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# NOISE CONTOURS FOR SHORT AND MEDIUM RANGE TRANSPORT AIRCRAFT AND BUSINESS AIRCRAFT

TECHNICAL REPORT



March 1965

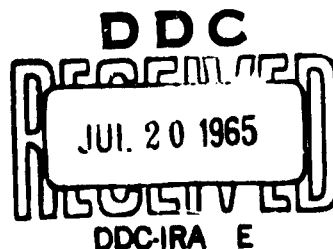
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by

Dwight E. Bishop

Bolt Beranek and Newman Inc.  
15808 Wyandotte Street  
Van Nuys, California 91406

Under Contract FA64WA-4949



for

## FEDERAL AVIATION AGENCY

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NOISE CONTOURS FOR SHORT AND MEDIUM RANGE  
TRANSPORT AIRCRAFT AND BUSINESS AIRCRAFT

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## ABSTRACT

Generalized noise contours, in terms of the perceived noise level, are presented for takeoff and landing operations of:

- a) two and three engine, short and medium range turbojet and turbofan transport aircraft, (Boeing 727, BAC 1-11, Douglas DC-9 and Sud Aviation Caravelle 3 and 6);
- b) multi-engine turbojet and turbofan business aircraft (Jet Commander 1121, Dassault Falcon, Hawker Siddeley D.H. 125, Lear Jet 23, Lockheed JetStar and North American Sabreliner); and
- c) two-engine propeller transport and business aircraft.

Estimates of ground runup noise for aircraft in groups a) and b) above are also presented. The noise contours are based on noise measurements and estimates.

The noise contours extend the scope of aircraft noise information for land use planning in the vicinity of airports. The noise information should be particularly helpful in describing the noise environment in and about smaller airports not regularly handling military or large civil jet transport aircraft.

## TABLE OF CONTENTS

	<u>Page</u>
ABSTRACT . . . . .	1
LIST OF FIGURES . . . . .	111
I. INTRODUCTION . . . . .	1
II. ANALYSIS METHODS . . . . .	3
III. VARIATION OF PERCEIVED NOISE LEVEL WITH DISTANCE FOR AIRCRAFT IN FLIGHT . .	6
A. Jet Aircraft . . . . .	6
B. Two-Engine Propeller Aircraft . . .	16
IV. TAKEOFF AND LANDING PROFILES . . . . .	23
V. GROUND RUNUP CONTOURS . . . . .	27
REFERENCES . . . . .	28
APPENDIX A . . . . .	A-1

## LIST OF FIGURES

	<u>Page</u>
1. Generalized Variation of Perceived Noise Level With Distance for Civil Medium and Short Range Jet Transport Aircraft and Business Jet Aircraft . . . .	7
2. Variation of Perceived Noise Level With Distance for Medium and Short Range Turbofan Transport Aircraft - Takeoff Power . . . . .	9
3. Variation of Perceived Noise Level With Distance for Business Turbojet and Turbofan Aircraft - Takeoff Power . .	10
4. Typical Takeoff Noise Spectra at 1000 ft Distance - Boeing 727, Jet Commander 1121, North American Sabreliner . . . . .	13
5. Variation of Perceived Noise Level With Distance for Various Transport and Business Jet Aircraft - Approach Power . . . . .	14
6. Typical Approach Noise Spectra at 1000 ft Distance - Boeing 727, Jet Commander 1121, North American Sabreliner . . . . .	15
7. Generalized Variation of Perceived Noise Level With Distance for Two Engine Propeller Transport and Business Aircraft . . . . .	17
8. Typical Takeoff Noise Spectra at 1000 ft Distance - Two Engine Propeller Aircraft . . . . .	20
9. Normalized Takeoff Noise Spectra - Two Engine Propeller Aircraft . . . . .	21

## LIST OF FIGURES (Continued)

	<u>Page</u>
10. Typical Approach Noise Spectra at 1000 ft Distance - Convair 340 and Fairchild F-27 . . . . .	22
11. Generalized Takeoff Profile for Medium and Short Range Jet Transport Aircraft (Boeing 727, BAC 1-11, Douglas DC-9, and Caravelle Series 3 and 6) and Business Jet Aircraft . . .	24
12. Generalized Takeoff Profile for Two Engine Propeller Transport and Business Aircraft . . . . .	25

## APPENDIX A

A-1	Generalized Variation of Perceived Noise Level With Distance for Civil Medium and Short Range Jet Transport Aircraft and Business Jet Aircraft
A-2	Generalized Variation of Perceived Noise Level With Distance for Two Engine Propeller Transport and Business Aircraft
A-3	Generalized Takeoff Profile for Medium and Short Range Jet Transport Aircraft (Boeing 727, BAC 1-11, Douglas DC-9, and Caravelle Series 3 and 6) and Business Jet Aircraft
A-4	Generalized Takeoff Profile for Two Engine Propeller Transport and Business Aircraft

## I. INTRODUCTION

This report presents estimates of the noise exposure during takeoff and landing operations of a variety of aircraft in three general classifications:

- a) two and three engine, short and medium range turbojet and turbofan transport aircraft
- b) multi-engine turbojet and turbofan business aircraft
- c) two-engine propeller aircraft (transport and business).

The report also provides estimates of the noise due to ground runups of aircraft engines for aircraft in classifications a) and b) above.

These noise estimates are intended to extend and supplement the scope of the noise information given in the report "Land Use Planning Relating to Aircraft Noise" issued by the FAA as a technical report of Bolt Beranek and Newman Inc. in October 1964\* (hereafter referred to as simply the Land Use Report).

The noise information, presented in the form of noise contours, forms a basis for estimating community response to aircraft noise, as described in the Land Use Report. The noise contours also form a basis for evaluating aircraft noise compatibility for land uses other than residential in accordance with the procedures given in Reference 1.

The Land Use Report provided information on military jet aircraft, four-engine propeller transport aircraft, the larger civil jet transports, and the larger civil helicopters. This noise information is well suited for determining the noise exposure in the vicinity of military air bases and those airports served by large civil aircraft.

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\* Also published by the Department of Defense as a Tri-Service Manual "Land Use Planning With Respect to Aircraft Noise" given the following designations: AFM 86-5, TM 5-365 and NAVDOCKS P-98.

However, because of the sharp increase in general aircraft activity, the rapid introduction of the smaller jet transports and the rapid development of land in the vicinity of airports, there is also increased need for noise information helpful in land planning for those smaller airports not regularly exposed to noise from military aircraft or the larger civil transports. This report helps fill that need by presenting, in compact form, noise information for the newer and smaller jet transports and business aircraft, as well as for smaller propeller aircraft.

The noise contours are given in Appendix A together with a table showing the appropriate contour to be selected for the different types of aircraft. Appendix A may be used directly as an attachment to the Land Use Report, without reference to the remainder of this report. The following sections of the report discuss the analysis procedure, sources of information, and some of the detailed noise information from which the generalized contours were derived.



## II. ANALYSIS METHODS

The noise level information is presented in this report in terms of the perceived noise level expressed in PNdB. The perceived noise level has been found to correlate well with the subjective evaluation of the noisiness of various types of aircraft noise and has become widely accepted as a means for describing aircraft noise both in this country and abroad. It is a calculated quantity based on physical measurements of the noise. The procedure for calculating perceived noise level is summarized in Attachment 4 of the Land Use Report; more complete descriptions of the concepts and calculation procedures are presented in Reference 2.

For flight operations, landing or takeoff, the perceived noise level given on the contours is the maximum occurring during the flight operation. Consistent with the Land Use Report contours, no corrections have been made for the relative duration of the noise produced by the flight operation.

The perceived noise level at any point on the ground, either underneath an aircraft in flight or around an aircraft running up on the ground, depends on the following factors:

- a) Type of aircraft (specifically the type of engine)
- b) engine power setting
- c) distance to aircraft.

To develop a noise contour, in general, one needs to determine the variation in perceived noise level with distance to the aircraft, and the geometrical orientation and distances between the aircraft and ground positions. For a flight operation at a particular engine power setting, one can construct a noise contour based upon:

- a) a graph or table giving the perceived noise level as a function of distance between aircraft and observer, and
- b) a flight profile which specifies the aircraft altitude in terms of distance from the runway.

To construct a noise contour for ground runup operations, at a particular engine power setting, one needs:

- a) a graph showing the variation of perceived noise level with angle at a constant distance about the aircraft
- b) a graph showing the variation of perceived noise level with distance at different angles around the aircraft.

To construct the generalized noise contours given in this report, i.e., contours that apply to one or more aircraft or one or more operating conditions, it is necessary to assemble detailed information on the noise and operational characteristics of the particular aircraft involved. Then, from comparison of the characteristics for individual aircraft, one or more curves are developed which approximate the range of values to be encountered. Such a procedure necessarily involves selecting one curve to represent a range in values. Approximate tolerance limits for the generalized curves are indicated throughout the report.

The major sources of information presented in this report are:\*

- a) numerous studies conducted by Bolt Beranek and Newman Inc. (BBN) for the Port of New York Authority, and various aircraft manufacturers where extensive photographic (positional) and acoustical data were obtained during takeoff, landing and runup operations under controlled aircraft operating conditions.
- b) noise estimates or measurements provided by airframe or engine manufacturers, and aircraft performance information provided by airframe manufacturers.

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\* The scope of this study did not include extensive field noise measurements. However, a number of noise measurements were made at several local airports to acquire data for the smaller two-engine piston aircraft. These measurements were taken in conjunction with a study of helicopter noise, also undertaken as part of this contract.

- c) data supplied by the Federal Aviation Agency on operations and acoustical characteristics of civil aircraft.<sup>3/</sup>
- d) numerous studies conducted by BBN in the vicinity of civil airports and military air bases where accurate positional and acoustical data were obtained during routine takeoff and landing operations, but where detailed information concerning aircraft operating conditions (power settings, operating gross weight, etc.) was lacking.

Since field noise data were not available for some of the aircraft covered in this report, noise estimates as well as noise measurements were utilized. In the following sections and in the figures, noise level estimates are distinguished from data directly substantiated by measurements. In the case of the smaller two-engine piston aircraft, which encompass a large range of old and new aircraft, the noise estimates presented are based upon measurements of several of the many different types of aircraft falling within this rather broad category.

### III. VARIATION OF PERCEIVED NOISE LEVEL WITH DISTANCE FOR AIRCRAFT IN FLIGHT

#### A. Jet Aircraft

The variations of perceived noise level with distance used in constructing the noise contours for jet aircraft in Appendix A (Contour Sets 9A, 10A and 11A) are shown in Fig. 1. The curves for takeoff and approach thrust shown in the figure apply directly to the Boeing 727 and Douglas DC-9 aircraft. Perceived noise level corrections for other transport and business aircraft are listed in the figure. Note from the table in Fig. 1 that the takeoff curve also applies directly to the small business turbojet aircraft, such as the Jet Commander 1121, Lear Jet 23, Lockheed JetStar, and the North American Sabreliner.

These generalized curves are based on acoustical measurements on the Boeing 727, Jet Commander 1121, Hawker Siddeley D.H. 125, Lockheed JetStar, North American Sabreliner, and the Caravelle plus estimates of the noise characteristics for the BAC 1-11, Douglas DC-9, Lear Jet 23 and the Dassault Falcon. The variations of perceived noise level with distance for some of the individual aircraft at takeoff thrust are shown in Figs. 2 and 3. Figure 2 shows perceived noise level for the small and medium range turbofan aircraft, while Fig. 3 shows the perceived noise levels for five business type jet aircraft, four powered by turbojet engines and one with turbofan engines.

Where detailed noise measurements were available, the curves in Figs. 2 and 3 were generated by first defining the octave band noise spectra for a particular aircraft at a reference distance of 1000 ft. The noise spectra at various other distances were then calculated using standard air attenuation values and estimates of the directional characteristics of the noise field. Perceived noise levels were then calculated from the octave band values.

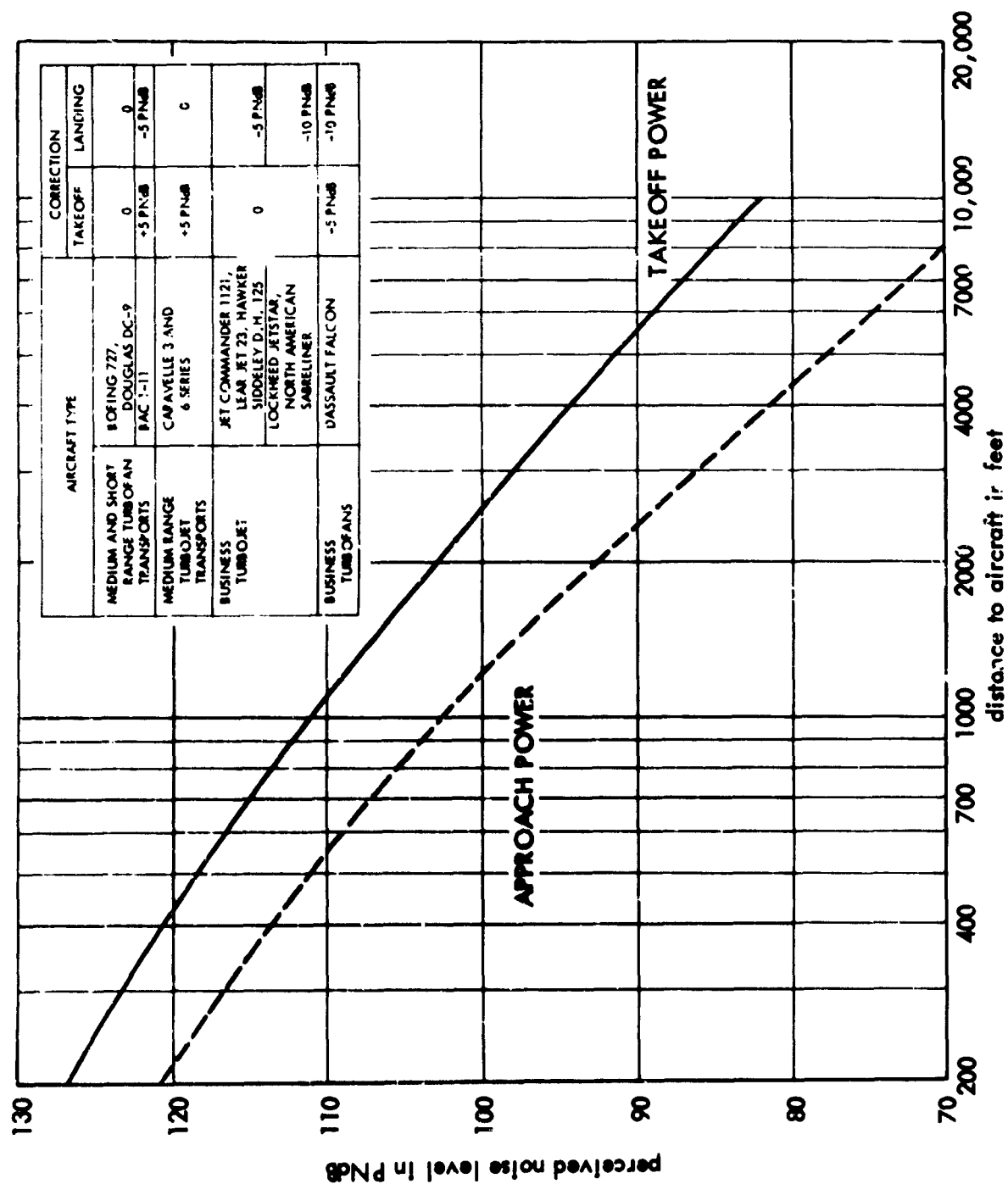


FIGURE 1. GENERALIZED VARIATION OF PERCEIVED NOISE LEVEL WITH DISTANCE FOR CIVIL MEDIUM AND SHORT RANGE JET TRANSPORT AND BUSINESS JET AIRCRAFT

The air attenuation values used in calculating the octave band spectra are listed below.

AIR ATTENUATION VALUES  
USED IN PREPARING FLIGHT NOISE CONTOURS

OCTAVE BAND, cps	Attenuation, db/1000 ft	
	Current Report	Land Use Report
20-75	0	0
75-150	0	0.15
150-300	0	0.3
300-600	0.6	0.6
600-1200	1.1	1.2
1200-2400	2.5	2.4
2400-4800	6.2	4.8
4800-10,000	11.3	10.0

These attenuation values are slightly different from those used in preparing the Land Use Report (listed in the third column of the above table) and those in the various BBN reports prepared for the Port of New York Authority. Compared to the Land Use Report attenuation values, the current attenuation values are smaller at frequencies below 300 cps and are slightly greater at frequencies above 2400 cps. Because of the smaller low frequency attenuation values,

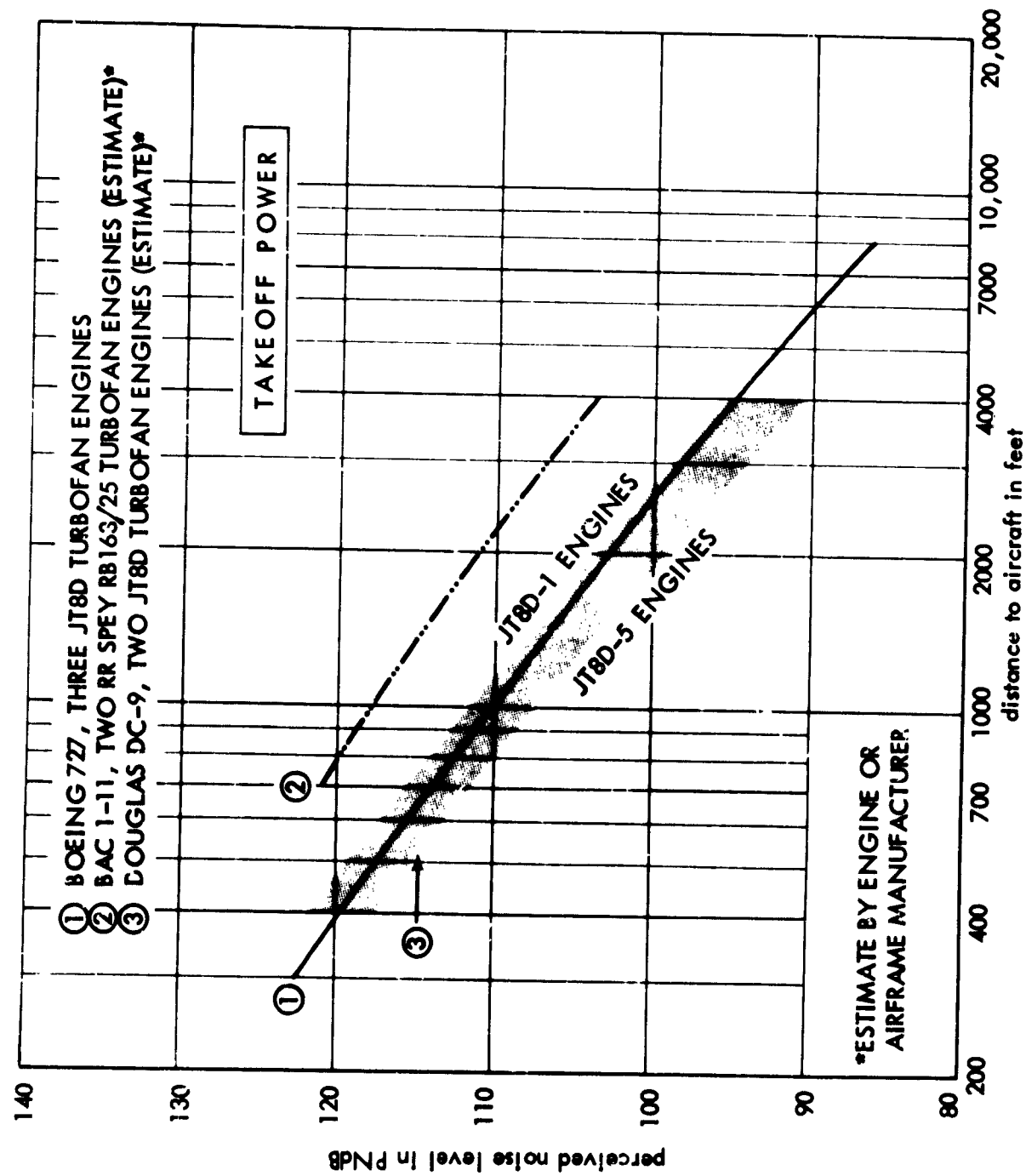


FIGURE 2. VARIATION OF PERCEIVED NOISE LEVEL WITH DISTANCE FOR MEDIUM AND SHORT RANGE TURBOFAN TRANSPORT AIRCRAFT - TAKEOFF POWER

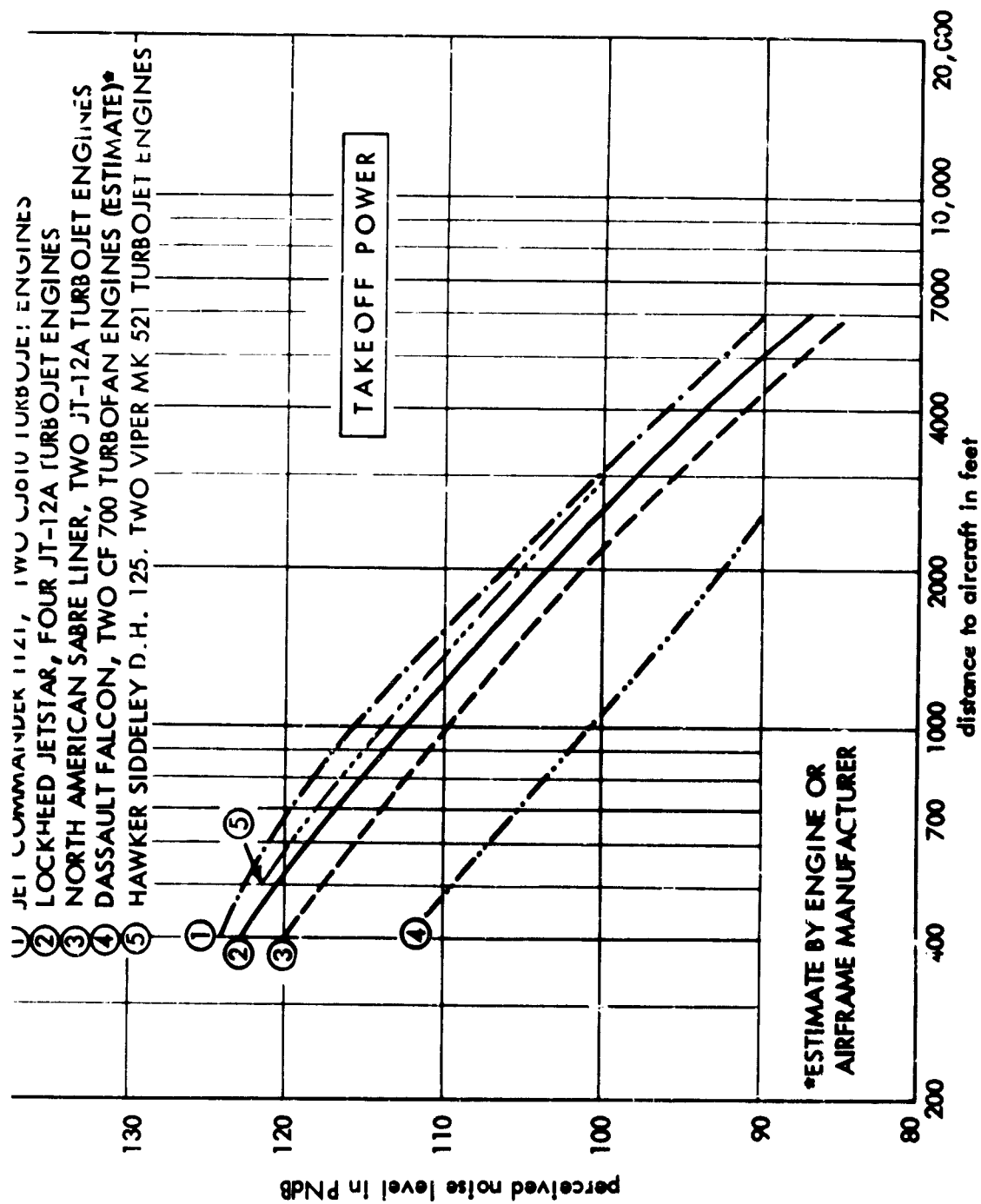


FIGURE 3. VARIATION OF PERCEIVED NOISE LEVEL WITH DISTANCE FOR BUSINESS TURBOJET AND TURBOFAN AIRCRAFT - TAKEOFF POWER



the attenuation values used in this report result in perceived noise level curves which decrease with distance more slowly at large distances from the aircraft.

In Fig. 2, noise estimates for the DC-9 are shown as a cross-hatched band. The upper edge of the band represents estimates for the DC-9 powered with JT8D-1 engines of 14,000 lbs thrust each; the lower edge, the JT8D-5 engines of 12,000 lbs thrust each. The estimates for the BAC 1-11 are for the aircraft fitted with RB 163/25 engines of 11,000 lbs takeoff thrust (American Airlines version).\*

Comparison of Figs. 2 and 3 shows that the noise levels produced by the business turbojet aircraft are approximately the same as those produced by the turbofan transports, the 727 and DC-9. For example, at 1000 ft the perceived noise levels for the business turbojet aircraft range from 110 to 116 PNdB while for the 727 and DC-9, the noise levels range from 108 to 112 PNdB. Thus one generalized curve for takeoff thrust fits the noise characteristics of the 727, DC-9 and the four turbojet business aircraft with a spread of about  $\pm 3$  to 4 PNdB over most of the distance range. A +5 PNdB correction, as given in the table in Fig. 1, accounts for the increased noise of the BAC 1-11 and the Caravelle series 3 and 6 aircraft. A -5 PNdB correction provides a relatively conservative correction for the Dassault Falcon powered with small turbofan engines.

Compared to the corresponding curves in the Land Use Report (the civil turbofan curve in Fig. 3-2 and the curve for military Flight Groups 6 and 9 in Fig. 3-3) the takeoff power curve of Fig. 1 predicts noise levels slightly lower for slant distances less than about 3000 ft and slightly higher for slant distances greater than about 4000 ft. For example, at 1000 ft distance the curve of Fig. 1 predicts 111 PNdB while the corresponding Land Use Report curves predict 114 PNdB. At 10,000 ft, Fig. 1 predicts 82 PNdB, 2 PNdB higher than the corresponding Land Use Report curves.

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\* These engines are slightly greater in thrust than the RB 163-2 engines of 10,410 lbs thrust powering the Braniff Airways aircraft.

The fact that the perceived noise level curves for some of the business turbojet aircraft coincide with the perceived noise level curves for some of the turbofan powered transports, already noted above, well illustrates the relative noise advantage of some of the turbofan engines compared to turbojet engines at high thrust settings. For example, the takeoff thrust of the Boeing 727 is approximately 3.5 times the takeoff thrust of the Lockheed JetStar, yet the takeoff perceived noise levels are approximately the same for the two aircraft.

Differences in the noise characteristics of turbojet and turbofan aircraft are also apparent when comparing the octave band noise spectra. Figure 4 provides such a comparison by showing the typical octave band noise spectra at takeoff power at 1000 ft distance for the Boeing 727, the Jet Commander 1121, and the North American Sabreliner.

The variation of perceived noise level with distance at approach power settings for specific aircraft is shown in Fig. 5. Curves for seven transport and business jet aircraft are shown.\* From Fig. 5, it can be seen that there is considerable spread in the noise level data for the various aircraft. At 1000 ft the noise levels range from about 87 to 105 PNdB. It is also evident from Fig. 4 that the acoustical advantage of the turbofan engine compared to the straight turbojet engine is much less at approach power settings. For example, at 1000 ft, the approach noise levels of the 727 range from 15 to 17 PNdB above the noise levels produced by the smaller business turbojet aircraft.

The curves in Fig. 5 show somewhat greater variation in slope than the perceived noise level curves for takeoff power. This variation results largely from the greater differences in spectrum shape at approach power settings. These differences are illustrated in Fig. 6 which shows the octave band noise spectra at 1000 ft for the 727, the

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\* A separate curve is now shown for the DC-9 since the DC-9 noise levels on approach are estimated to be approximately 2 PNdB less than those for the Boeing 727. Likewise, the curve for the Lear Jet 23 is assumed to be identical with that for the Jet Commander 1121.

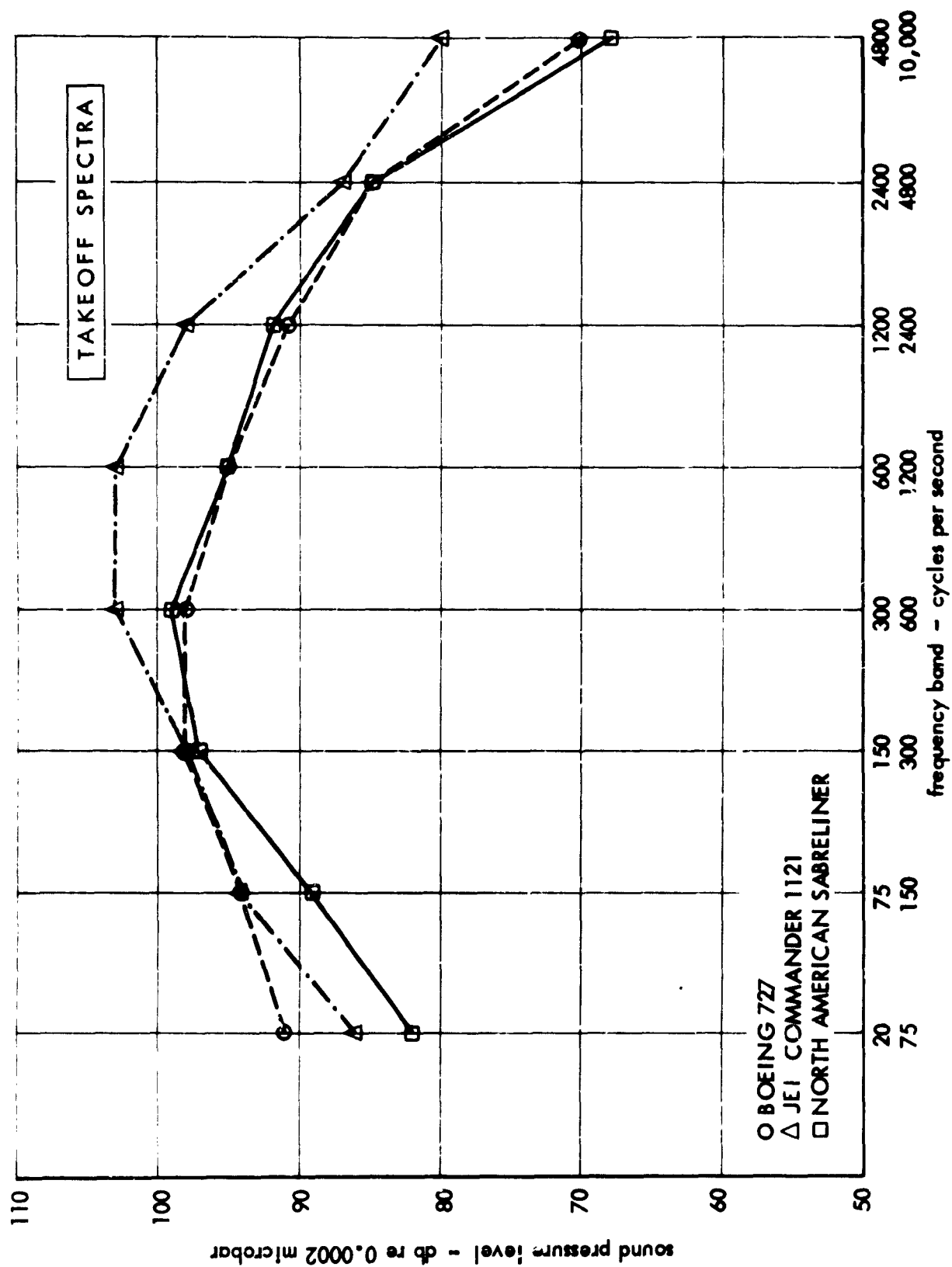


FIGURE 4. TYPICAL TAKEOFF NOISE SPECTRA AT 1000 FT. DISTANCE -  
BOEING 727, JET COMMANDER 1121, NORTH AMERICAN SABRELINER

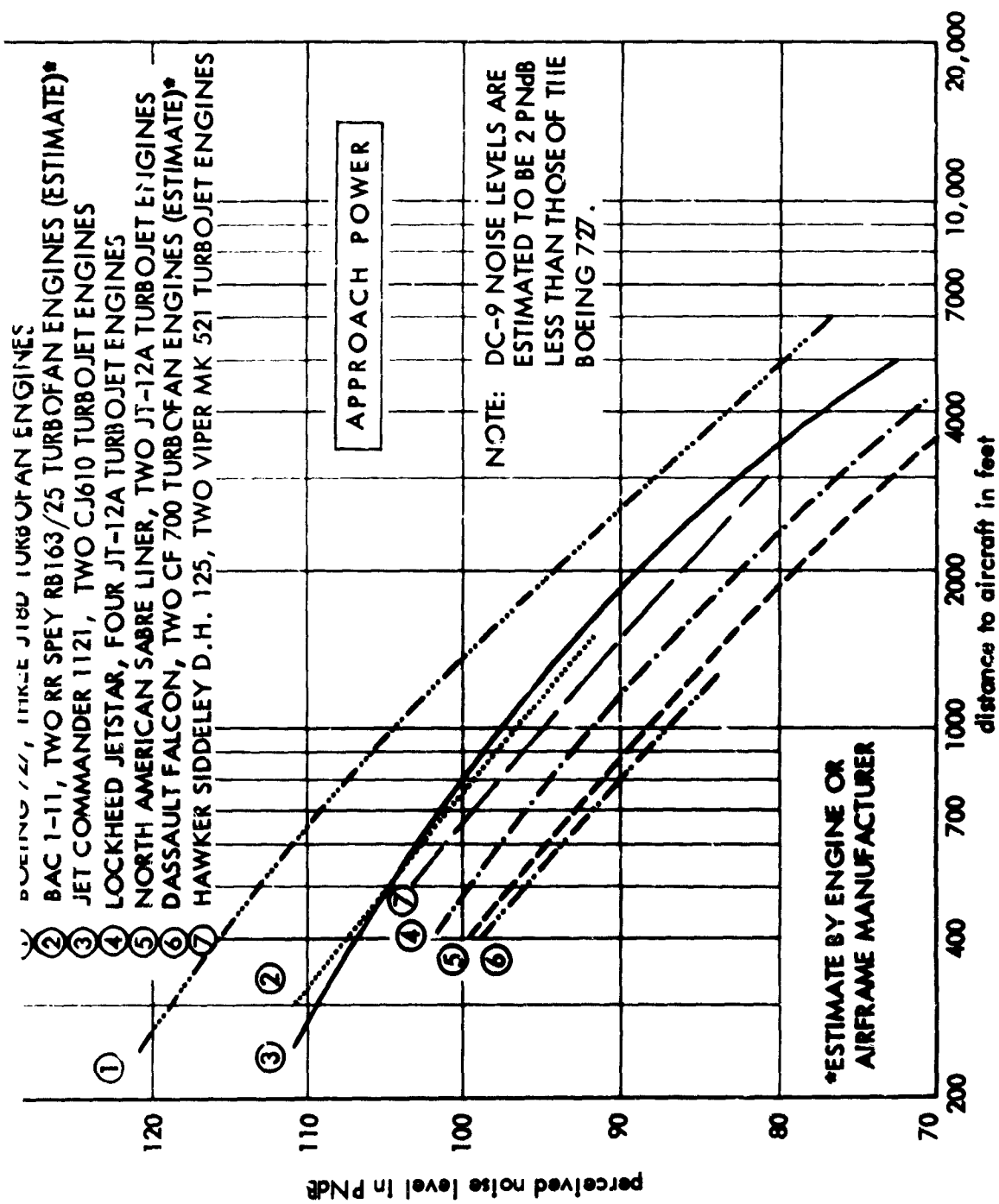


FIGURE 5. VARIATION OF PERCEIVED NOISE LEVEL WITH DISTANCE FOR VARIOUS TRANSPORT AND BUSINESS JET AIRCRAFT - APPROACH POWER

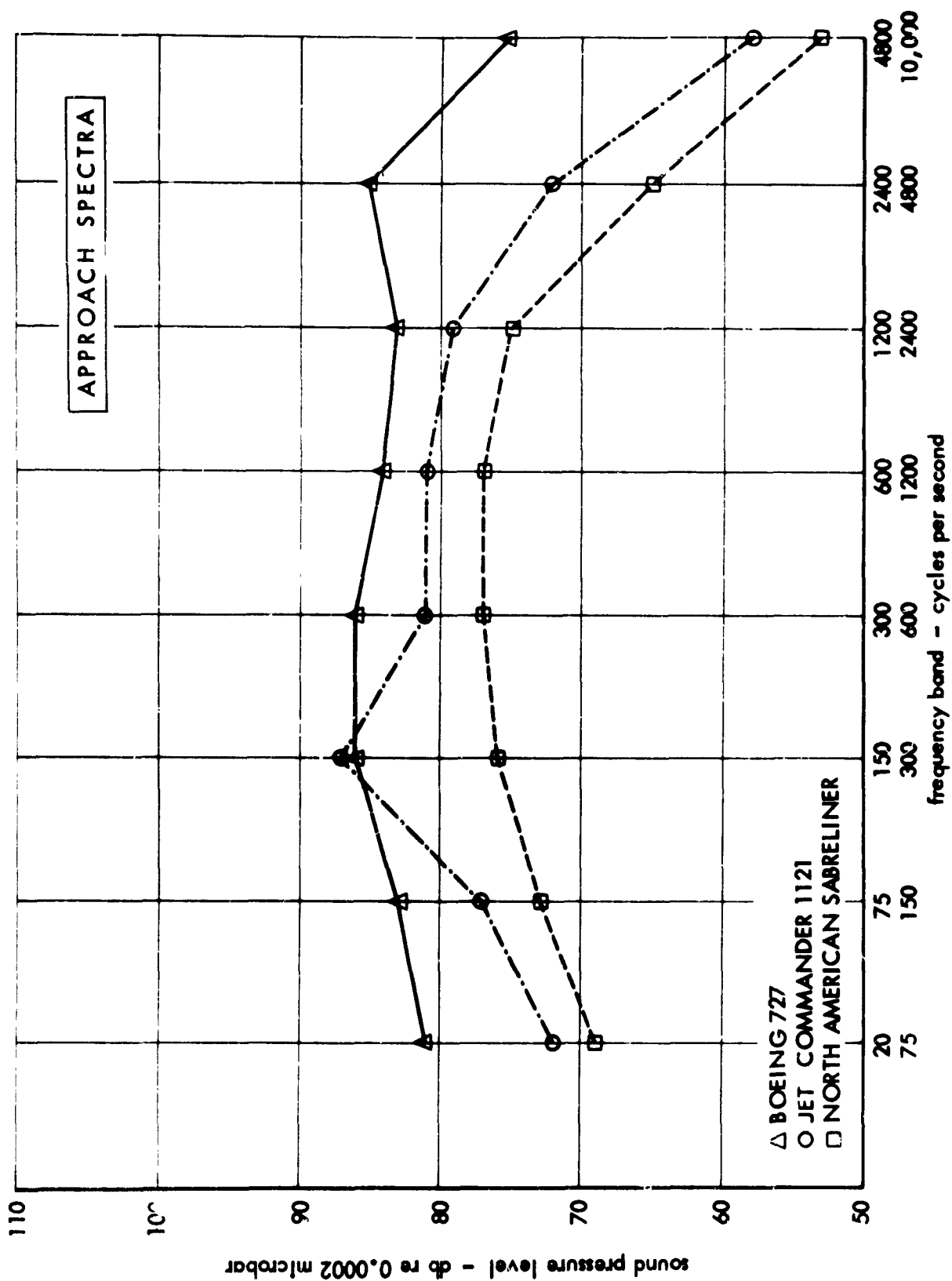


FIGURE 6. TYPICAL APPROACH NOISE SPECTRA AT 1000 FT. DISTANCE -  
BOEING 727, JET COMMANDER 1121, NORTH AMERICAN SABRELINER

Jet Commander 1121, and the North American Sabreliner. The irregularities in the octave band spectra suggest the presence of strong pure tone components in much different frequency ranges for the 727 and Jet Commander 1121.

The generalized curve for approach power shown in Fig. 1 fits the perceived noise level curves for the 727 and DC-9 with a spread of approximately  $\pm 2$  PNdB. Corrections of -5 and -10 PNdB, as indicated in Fig. 1, provide a fit for the other aircraft with a spread of about  $\pm 3$  PNdB.

The generalized approach curve of Fig. 1 is quite similar to that given for turbojet and turbofan aircraft in Figs. 3-2 and 3-3 of the Land Use Report. The curve in Fig. 2 is approximately 1 PNdB higher than the Land Use Report curves at distances of 1000 ft or greater. At distances less than 500 ft the curve in Fig. 2 falls below the Land Use Report curves.

#### B. Two-Engine Propeller Aircraft

Figure 7 shows three generalized curves depicting the variation of perceived noise level with distance for two-engine piston and turboprop transport aircraft. The upper curve is for METO (maximum except takeoff) power for piston transports such as the DC-3, Convair 240, 340 and 440, Martin 202 and 404, etc. The middle curve is for two-engine turboprop aircraft, such as the Fairchild F-27 and the Grumman Gulfstream, at takeoff power. The lower curve shows perceived noise level at approach power settings for the above piston and turboprop aircraft.

These generalized curves also provide estimates of the variation in perceived noise level with distance for many of the lighter two-engine piston powered aircraft such as the Aero Commander, Beech 18 Series, Beech Baron, Cessna 310 Series, Piper Apache and Aztec, etc. For these aircraft and others powered by reciprocating engines, and falling in a gross weight range of about 3500 to 10,000 lbs, a correction of -10 PNdB should be applied to the METO power curve of Fig. 7. For approach power settings for these lighter piston aircraft, a correction of -10 PNdB should be applied to the approach power curve of Fig. 7.

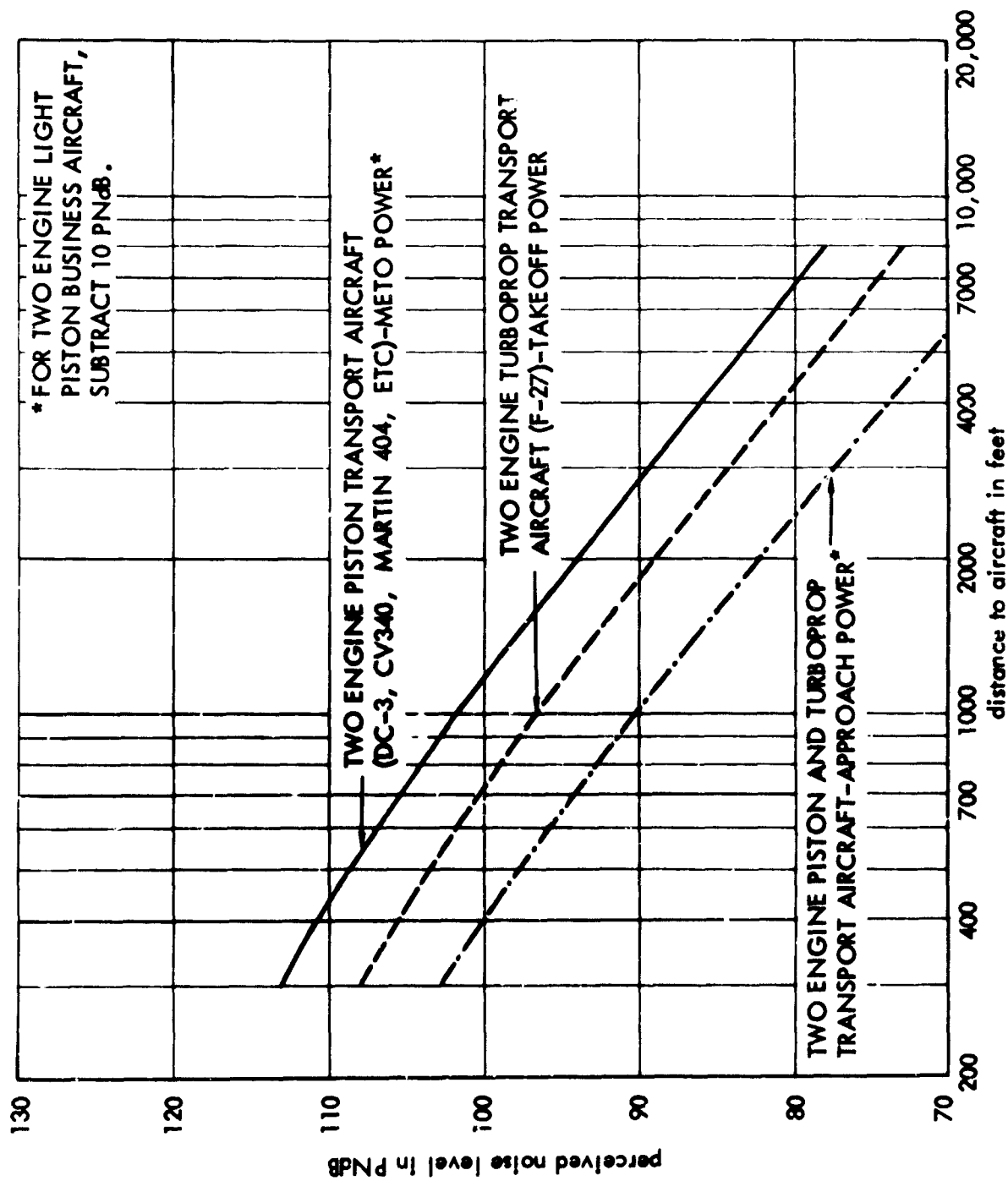


FIGURE 7 GENERALIZED VARIATION OF PERCEIVED NOISE LEVEL WITH DISTANCE

From the perceived noise level curves of Fig. 7, plus the flight profile curves (to be discussed later), the takeoff noise contours of Contour Set 9B in Appendix A were derived. One difference between these contours and the corresponding contours for four-engine propeller aircraft given in the Land Use Report (Contour Set 4) may be noted. In this report, for simplicity, the contour shows a single power reduction, from METO to climb power. Contour Set 4 includes two power reductions, an initial reduction from takeoff power to METO power immediately after takeoff, plus the second reduction from METO power to climb power. A 4 PNdB difference between METO and climb power has been assumed in this report consistent with the differences in the Land Use Report.

The noise data for Fig. 7 were obtained from measurements made in the vicinity of a number of civil and military airports. Aircraft measured include the Douglas DC-3, Convair 240 and 340, Martin 404, Fairchild F-27 and lighter piston-powered aircraft including the Aero Commander, Beech Baron, Beech 18 Series (C-45), Cessna Bobcat, Cessna 310, and Piper Aztec and Apache aircraft. Although noise levels and slant distances were measured accurately, information on the exact engine power settings and operating gross weights was usually unobtainable. Thus the field data represent information obtained under less well controlled operating conditions than those which are often available for many of the turbofan and turbojet transport aircraft.

To derive the generalized noise curves, the field noise data were first plotted in terms of perceived noise level-vs-distance for the different aircraft groupings. A curve was then fitted by eye to the data. As a second step the variation in perceived noise level with distance was checked for several specific types of aircraft. Several sets of field noise measurements, representing noise measurements of the same aircraft at different slant distances, were adjusted to a common distance of 1000 ft. A mean noise spectrum for the 1000 ft distance was then calculated. Using this spectrum, octave band spectra at other distances were calculated using the air attenuation values listed on page 8. Perceived noise levels were calculated from the octave band spectra; curves were then fitted to the plots of the perceived noise level versus distance. Comparison of these curves for specific aircraft with the curves fitted to the field data led to a refinement of the initial curves. The



resulting generalized curves of Fig. 7 fit the field data with a spread of about  $\pm 4$  PNdB. The curves of Fig. 7 are similar in shape and lie 2 to 3 PNdB below the corresponding Land Use Report curves (Fig. 3-1).

Some of the takeoff noise spectra for individual propeller aircraft are shown in Fig. 8. Although the range of absolute noise levels for the four aircraft shown in Fig. 8 is considerable, the spectrum shapes are similar except for the high frequency turbine noise component evident for the turboprop F-27. The similarity in the spectra is more clearly shown in Fig. 9 where each of the four spectra are plotted relative to their overall sound pressure level.

Typical approach noise spectra at 1000 ft for two propeller aircraft, the Convair 340 and the Fairchild F-27, are shown in Fig. 10. Here again a difference between turboprop and piston powered noise spectra is evident, with the pure tone component produced by the turboprop clearly in evidence in the 2400-4800 cps octave band.

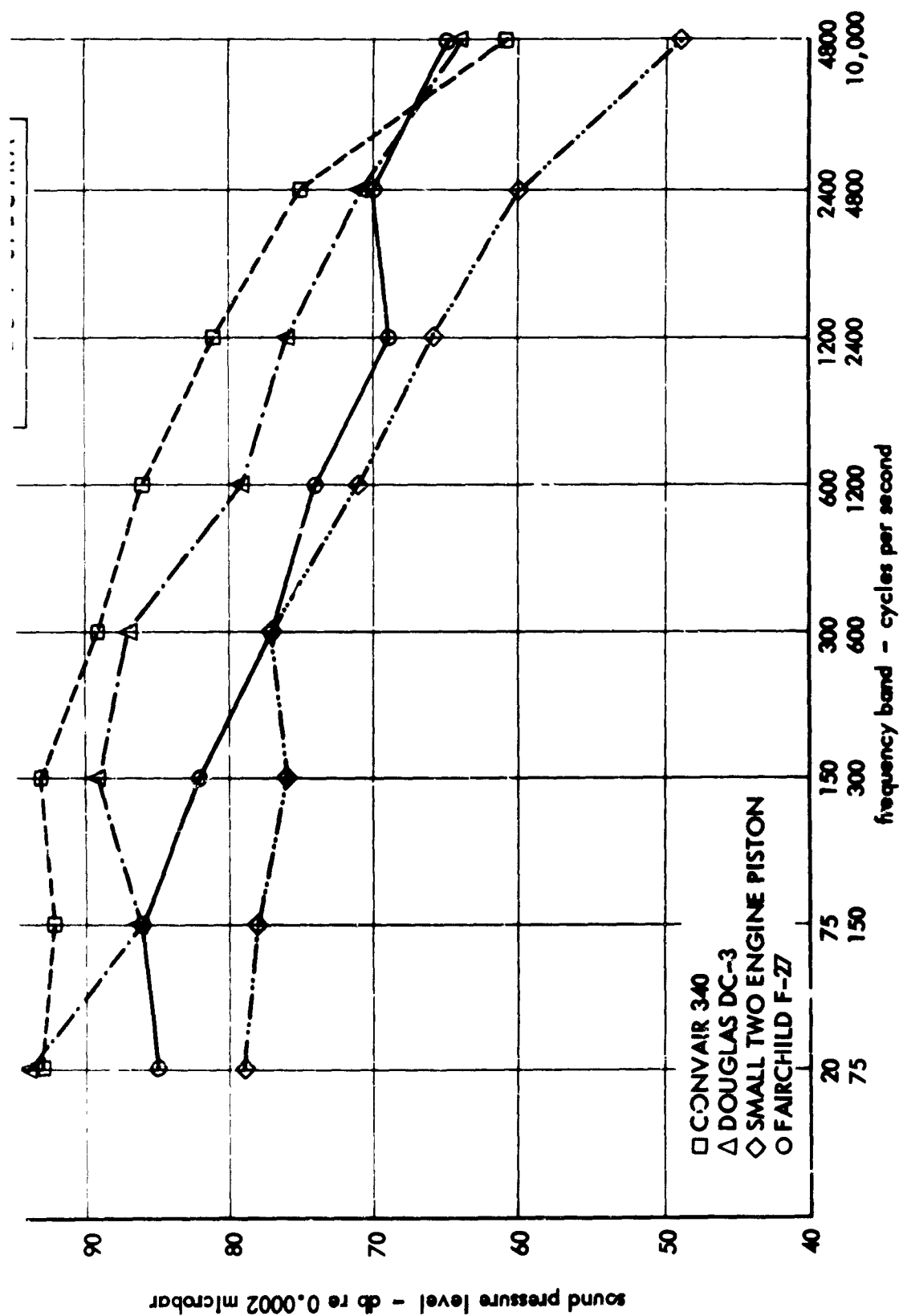


FIGURE 8. TYPICAL TAKEOFF NOISE SPECTRA AT 1000 FT.  
DISTANCE - TWO ENGINE PROPELLER AIRCRAFT

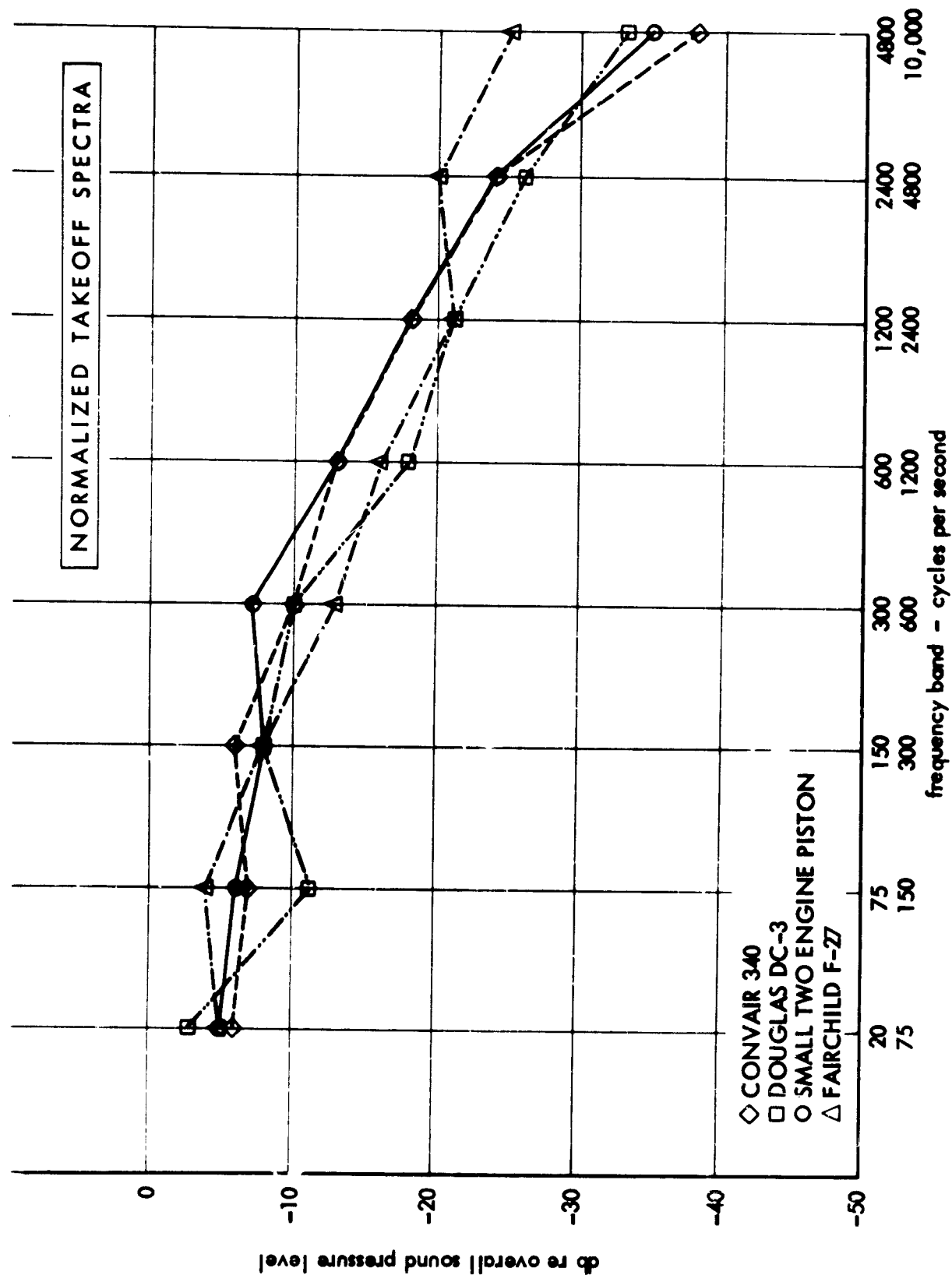


FIGURE 9. NORMALIZED TAKEOFF NOISE SPECTRA - TWO ENGINE PROPELLER AIRCRAFT

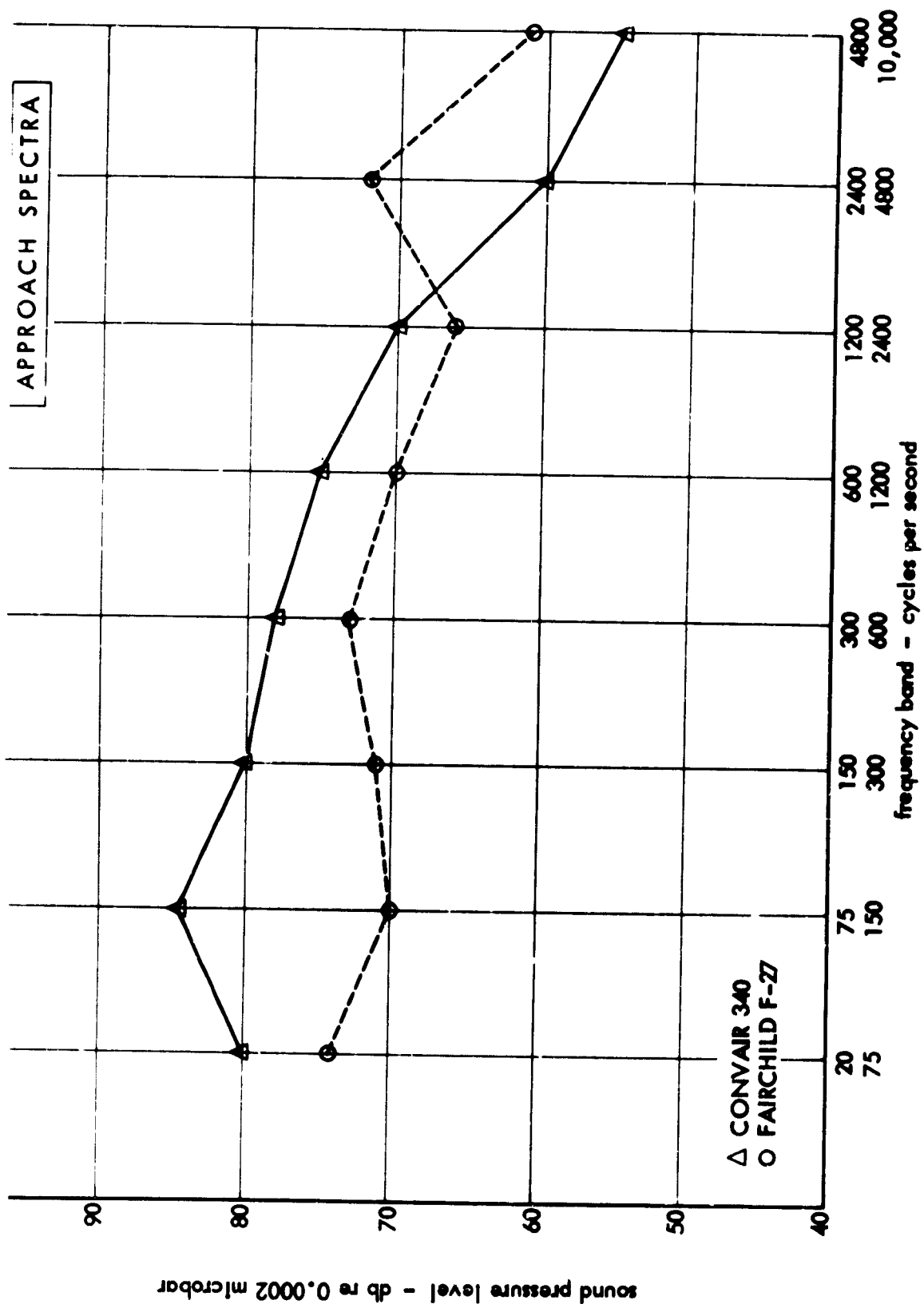


FIGURE 10. TYPICAL APPROACH NOISE SPECTRA AT 1000 FT.  
DISTANCE - CONVAIR 340 AND FAIRCHILD F-27

#### IV. TAKEOFF AND LANDING PROFILES

Figure 11 shows the generalized takeoff profile applicable for small and medium range jet aircraft and for business turbojet and turbofan aircraft. This profile was used in developing the takeoff noise contours in Contour Set 9A in Appendix A. The boundaries of the shaded area shown in Fig. 11 represent takeoff profiles at maximum gross weight and at approximately 85% gross weight under standard day, no wind conditions for the small and medium range civil jet transports (727, DC-9, BAC 1-11 and Caravelle). These boundaries were also found to correspond closely with the corresponding takeoff profiles for three of the four business jet aircraft for which performance information was available (Jet Commander 1121, D.H. 125, JetStar and Sabreliner).\*

The generalized takeoff profile line was drawn through the shaded area in such a manner that at any given distance from the start of takeoff roll the variation in altitude above and below the profile line would produce the same change in perceived noise level. Hence the generalized profile has not been drawn through the exact center of the shaded area. For the range of takeoff profiles shown in Fig. 11, the variation in perceived noise level is about  $\pm 4$  PNdB about the profile line for positions directly under the flight path located 10,000 ft or more from the start of the takeoff roll.

The takeoff profile in Fig. 11 is quite similar in slope to that shown for short to medium range flights of large civil jet transports in Fig. 3-6 of the Land Use Report. However the profile in Fig. 11 is displaced about 2000 ft towards the start of the takeoff roll, reflecting the shorter field lengths required for takeoffs of the smaller civil transport and business jet aircraft.

Figure 12 shows the generalized takeoff profile used in construction of Contour Set 9B for propeller aircraft. The shaded area represents the approximate range in expected profiles for two-engine piston and turboprop aircraft. The profile information summarized in the figure is based upon

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\* At the lower gross weights, the Sabreliner flight profile lies slightly above the shaded area of Fig. 11.

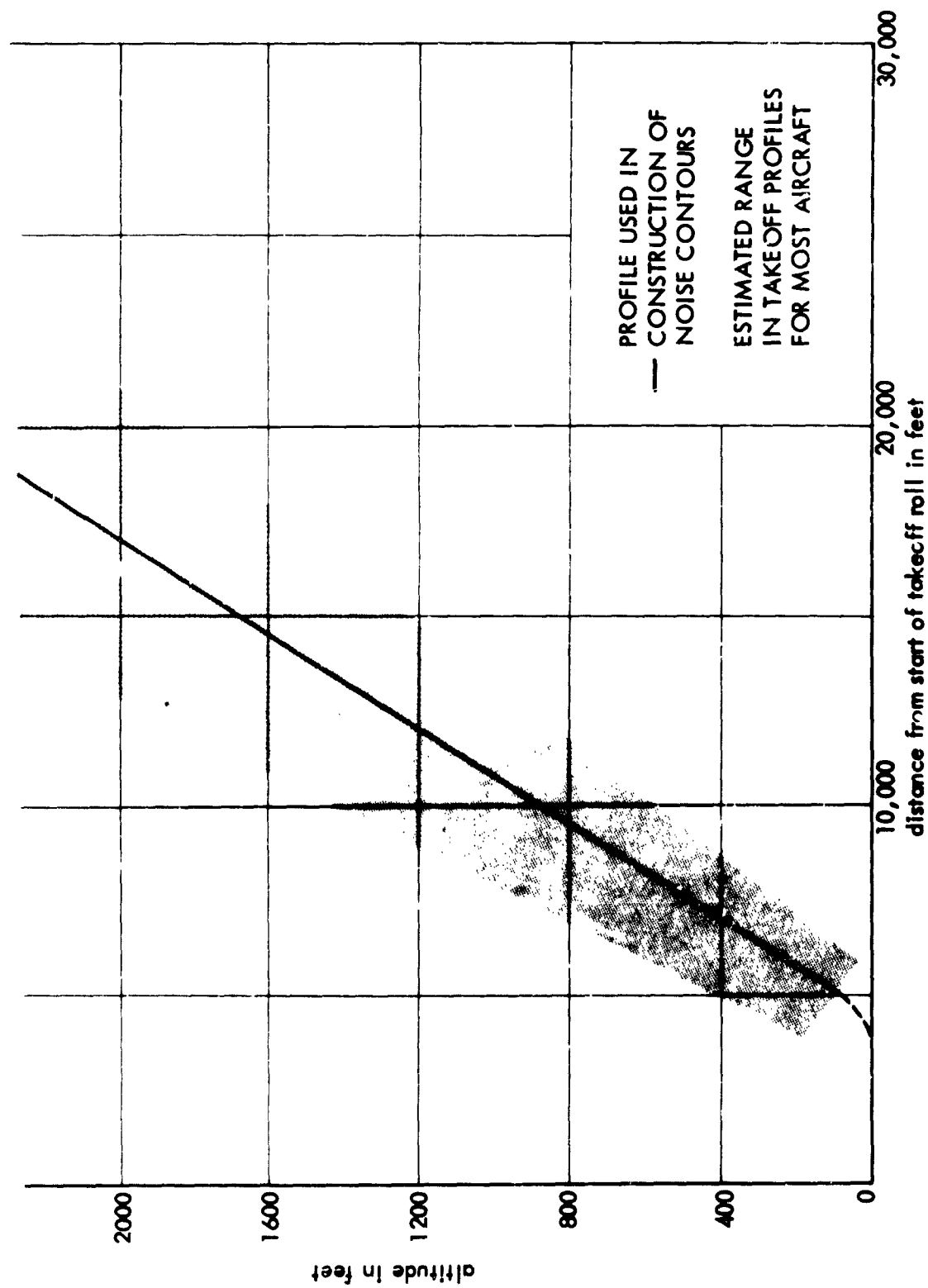


FIGURE 11. GENERALIZED TAKEOFF PROFILE FOR MEDIUM AND SHORT RANGE JET TRANSPORT AIRCRAFT (BOEING 727, BAC 1-11, DOUGLAS DC-9, AND CARAVELLE SERIES 3 AND 6) AND BUSINESS JET AIRCRAFT

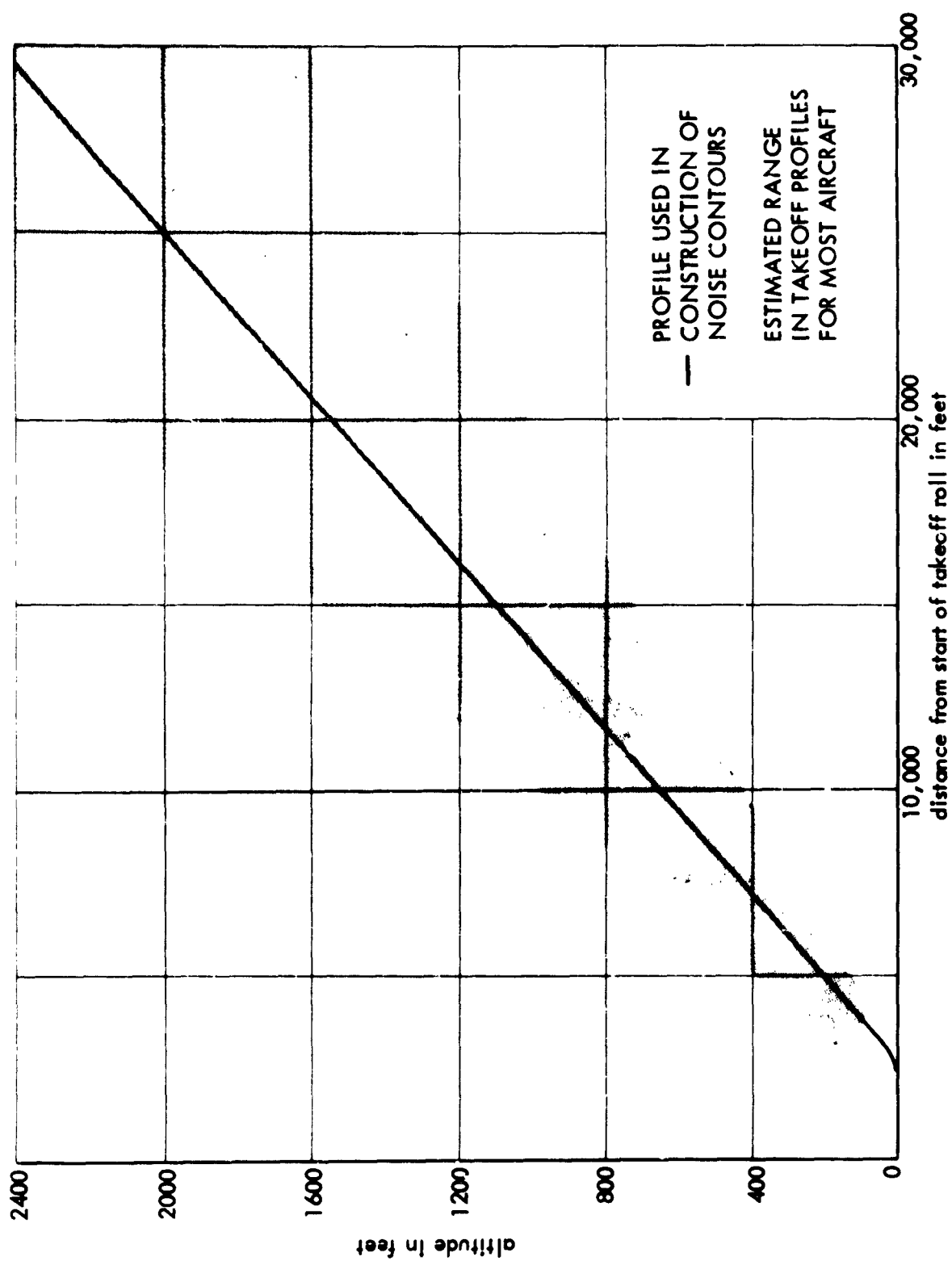


FIGURE 12. GENERALIZED TAKEOFF PROFILE FOR TWO ENGINE PROPELLER  
TRANSPORT AND BUSINESS AIRCRAFT

performance information for two-engine transport aircraft furnished by aircraft manufacturers, numerous observations of flight altitudes under takeoff flight paths at civil and military airfields, and information supplied by the FAA.<sup>4</sup> The profile information is based largely upon observations and flight information for the heavier two-engine aircraft, (DC-3, Convairs, Martin 404, and Fairchild F-27); hence it may not be entirely representative of take-off profiles for some of the smaller two-engine piston aircraft.

As in the previous figure, the takeoff profile line in Fig. 12 was drawn through the shaded area in such a manner that at a given distance from the start of takeoff roll the variation in altitude would be equivalent to the same change in perceived noise level above and below the profile line. The variation in perceived noise level is  $\pm 4$  FNdB about the profile line that has been used in constructing the noise contours for positions located directly under the flight path.

Two sets of landing noise contours are included in Appendix A, Contour Sets 10 and 11. These sets are based upon the same noise data, but different approach profiles. Contour Set 10 is based upon a  $3^\circ$  glide slope applicable to instrument (GCA and ILS) landings at civil airports and military air bases. This profile is consistent with that used in preparing the landing profiles in the Land Use Report.

Under VFR conditions the approach path for some aircraft, particularly the smaller ones, may lie well above the  $3^\circ$  glide slope. The combination of higher glide slope and the slightly lower power settings often accompanying the higher glide path leads to overestimation of noise levels when using a profile based upon a  $3^\circ$  glide slope. Therefore, as an aid in estimating noise levels in the vicinity of airports or runways handling VFR traffic, Contour Set 11 has been prepared. This contour set, based upon a higher glide slope of  $4\frac{1}{2}^\circ$ , may be used instead of Contour Set 10 for more accurate estimation of approach noise levels at airports or runways not equipped for handling instrument approaches. Contour Set 11 should not be used for predicting current or expected noise exposure for runways handling (or expected to handle) any appreciable number of instrument landings.



## V. GROUND RUNUP CONTOURS

Contour Set 12 in Appendix A presents contours for estimating the noise exposure produced by ground runups of civil and military turbofan engines. The noise contours apply directly to the ground runups of the 727 and DC-9 aircraft. Contour Set 12 should also be used for estimating the noise exposure resulting from ground runups of the turbofan engines in Boeing 707 and 720, Douglas DC-9 and Convair 990 aircraft. Contour Set 12 is thus recommended as a replacement for Contour Set 7 in the Land Use Report since it is based upon more complete noise information covering a wider range of engines.

Contour Set 12 is based upon study of the noise characteristics of the JT3D-1, JT8D-1, and CJ805-23 turbofan engines. The contours were developed by first examining the variation of perceived noise level with angle at a constant distance of 250 ft from the aircraft for the different engines, and constructing a generalized directivity plot. The variation of perceived noise level with distance was then determined for each engine at several angles.

Attenuation values used in determining the variation in PNdB with distance were the same as those used in preparing the runup contours in the earlier Land Use Report. They are based upon the inverse square reduction of sound, typical attenuation values for sound traveling through the air and over terrain, and the effects of a moderate wind (velocity gradient). These attenuation values for ground-to-ground propagation of sound are considerably greater than the air-to-ground attenuation values used in preparing the flight contours.

From the basic directivity curve and the attenuation plots at selected angles, the corresponding perceived noise levels were plotted as a function of distance on polar graph paper. Equal PNdB values were then connected to form the noise contours.

The three types of civil turbofan engines included in the study show a sizeable variation in directivity. As a result the spread in data about Contour Set 12 is about  $\pm 5$  PNdB. Contour Set 12 is similar to Contour Set 7 in the Land Use Report for angles of  $110^\circ$  or less; for larger angles (i.e., angles closer to the jet exhaust), Contour Set 12 predicts perceived noise levels greater than estimated from Contour Set 7.

#### REFERENCES

1. D. E. Bishop, "Development of Aircraft Noise Compatibility Criteria for Varied Land Uses," Part II of FAA SRDS Report No. RD-64-148 (December 1964).
2. K. D. Dryter, K. S. Pearsons, "Some Effects of Spectral Content, Duration and Rise Time of Sound on Perceived Noise Level," J. Acoust. Soc. Am., 35, 866-883 (1963) - also see: K. D. Kryter, K. S. Pearsons, "Modification of Noy Tables," J. Acoust. Soc. Am., 36, 394-397 (1964).
3. Federal Aviation Agency Contract Nos. F-2446 and FA-3191, Polysonics, Inc.
4. SAE ARP 866, "Standard Values of Atmospheric Absorption as a Function of Temperature and Humidity for Use in Evaluating Aircraft Flyover Noise," (1964).

## APPENDIX A

This Appendix presents perceived noise level contours for the takeoff and landing operations of the following types of civil aircraft:

- a) two and three engine, short and medium range turbo-jet and turbofan transports
- b) multi-engine small business turbojet and turbofan aircraft
- c) two-engine piston and turboprop aircraft, both transport and business.

These contours permit the determination of the noise level in PNdB over a wide area beneath and off to the side of a flight path. The Appendix also includes a runup noise contour for estimating the noise from ground runups of civil and military turbofan engines.

The noise contours for flight operations supplement the noise contours given in Attachment 2 of the report "Land Use Planning Relating to Aircraft Noise" issued by the FAA as a Technical Report of Folt Beranek and Newman Inc. in October 1964.\* The runup noise contour (Contour Set 12) replaces Contour Set 7 of Attachment 2; it is based upon a more extensive range of turbofan engines than Contour Set 7. The noise contours are to be used in the same manner as those in Attachment 2 following exactly the same procedures outlined in the referenced report.

By providing noise estimates for a variety of smaller and more recent aircraft not included in Attachment 2, this Appendix should extend the usefulness of the referenced report as a land use planning aid at both large and small airports. The noise contours may also prove useful in determining aircraft noise compatibility for varied land uses, other than residential, following the procedures outlined in Part II of the Federal Aviation Agency SRDS Report No. RD-64-148.

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\* This report has also been published by the Department of Defense as a Tri-Service Manual "Land Use Planning With Respect to Aircraft Noise" given the following designations: AFM 86-5, TM 5-365 and Navdocks P-98.

The appropriate contour for a specific problem can be selected by reference to Table A-I. This table shows, for different aircraft, the appropriate takeoff, landing, or ground runup contour to be used and the appropriate perceived noise level correction needed for the particular contour.

Two sets of landing contours are listed in Table A-I for each type of aircraft. Contour Set 10, based upon a 3° glide slope, should normally be used for estimating noise levels in the vicinity of airports served by scheduled commercial aircraft and in the vicinity of all runways equipped for instrument landings. Contour Set 11, based upon an approach path appreciably higher than 3°, may be used for estimating the noise due to landing operations at airports not served by scheduled commercial aircraft and not possessing instrument landing facilities. Contour Set 10 provides a higher estimate of noise levels at distances more than several thousand feet from the runway threshold.

Figures A-1, A-2, A-3 and A-4 present the generalized perceived noise level-vs-distance and flight profile information upon which Contour Sets 9, 10 and 11 are based. This information supplements the generalized curves given in Attachment 3.

Figure A-1 shows two curves depicting the variation of perceived noise level with distance for medium and short range jet transport and business jet aircraft. These curves were used in constructing Contour Sets 9A, 10A and 11A. One curve is for takeoff power, the other for approach power. The curves apply directly to the Boeing 727 and Douglas DC-9 aircraft. Perceived noise level corrections for other transport and business aircraft are listed in the figure.

Figure A-2 shows generalized perceived noise level versus distance curves for two-engine piston and turboprop aircraft. These curves were used in constructing Contour Sets 9B, 10B and 11B. The upper curve describes the noise output at METO power for two-engine piston transport aircraft such as the Douglas DC-3, Convair 340 and Martin 404. The middle curve describes the noise output at

takeoff power for two-engine turboprop transports (Fairchild F-27 and Grumman Gulfstream). The lower curve is for approach power for two-engine piston and turboprop transport aircraft. As noted in the figure, a correction of -10 PNdB should be applied to the upper and lower curves of Figure A-2 for estimates of the noise output of two-engine light piston business aircraft.

Figure A-3 shows the takeoff profile used in constructing Contour Set 9A. The boundaries of the shaded area shown in the figure represent the range of takeoff profiles at maximum gross weight and at approximately 85% gross weight under standard day, no wind conditions for two and three engine, small and medium range jet transport aircraft. These boundaries also depict the range of corresponding takeoff profiles for most multi-engine business jet aircraft. The generalized takeoff profile line shown in the figure was drawn through the shaded area in such a manner that, at any given distance from the start of takeoff roll, the variation in altitude above and below the profile line would produce the same change in perceived noise level.

Figure A-4 shows the generalized takeoff profile used in construction of Contour Set 9B for propeller aircraft. The shaded area represents the approximate range in expected profiles for two-engine piston and turboprop aircraft.

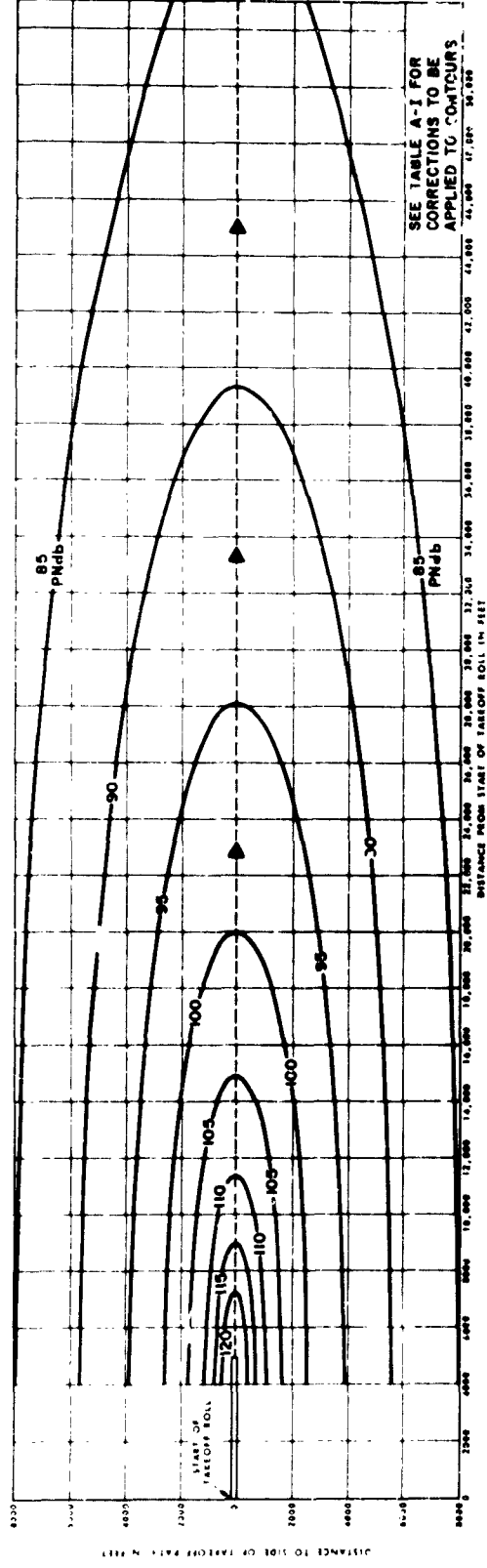
The landing profile used in preparing Contour Set 10 is based on a  $3^{\circ}$  glide slope, shown in Fig. 3-8 of Attachment 3. This landing profile is applicable to instrument landings (GCA and ILS) at civil airports and military air bases. In preparing Contour Set 11, applicable for VFR aircraft landings, a glide slope of  $4\frac{1}{2}^{\circ}$  was used. This glide slope forms the upper boundary of the shaded area shown in Fig. 3-8 of Attachment 3.

# CHART FOR SELECTING NOISE CONTOURS

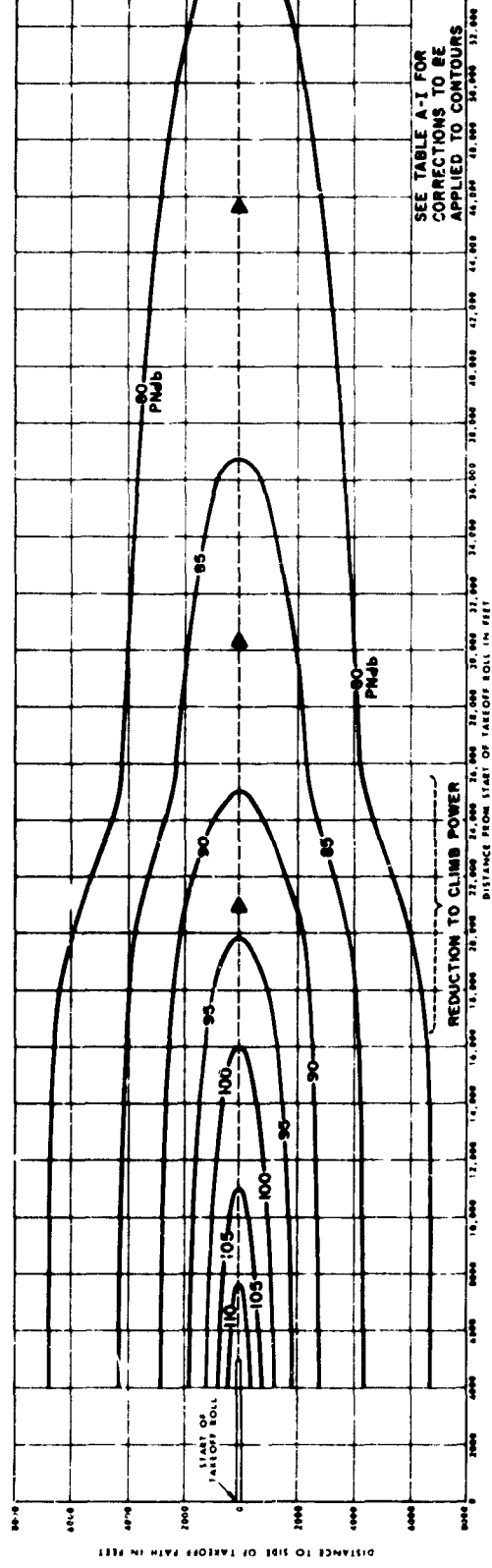
AIRCRAFT TYPE		OPERATION					
		TAKEOFFS		LANDINGS		RUNUPS	
		Contour Set	Corrections to Contour	Contour Set*	Corrections to Contour	Contour Set	Corrections to Contour
Medium and Short Range Turbofan Transports	Boeing 727, Douglas DC-9	9A	0	10A	0	12	0
	BAC 1-11	9A	+5 PNdB	10A	-5 PNdB	-	-
Medium Range Turbojet Transports	Caravelle (3 and 6 series)	9A	+5 PNdB	10A	0	6	0
	Jet Commander 1121, Lear Jet 23, Hawker Siddeley D.H. 125	9A	0	10A	-5 PNdB	8	0
	Lockheed Jet Star North American Sabreliner	9A	0	10A	-10 PNdB	8	-5 PNdB
Business Turboprops	Dassault Falcon	9A	-5 PNdB	10A	-10 PNdB	12	-10 PNdB
Two Engine Piston Transports	Douglas DC-3, 340, 440, Convair 240, 440, Martin 202, 404	9B	0	10B	0	X	
	Fairchild F-27, Grumman Gulfstream	9B	-5 PNdB	10B	0		
Two Engine Light Piston Business Aircraft**	Aero Commander, Beech 18 series, Cessna 310 series, Piper Apache and Aztec, etc.	9B	-10 PNdB	10B	-10 PNdB		

\* Contour Set 11 may be used instead of Contour Set 10 for estimating noise exposure at airports not possessing instrument landing facilities or where only a very small proportion of instrument approaches are made.

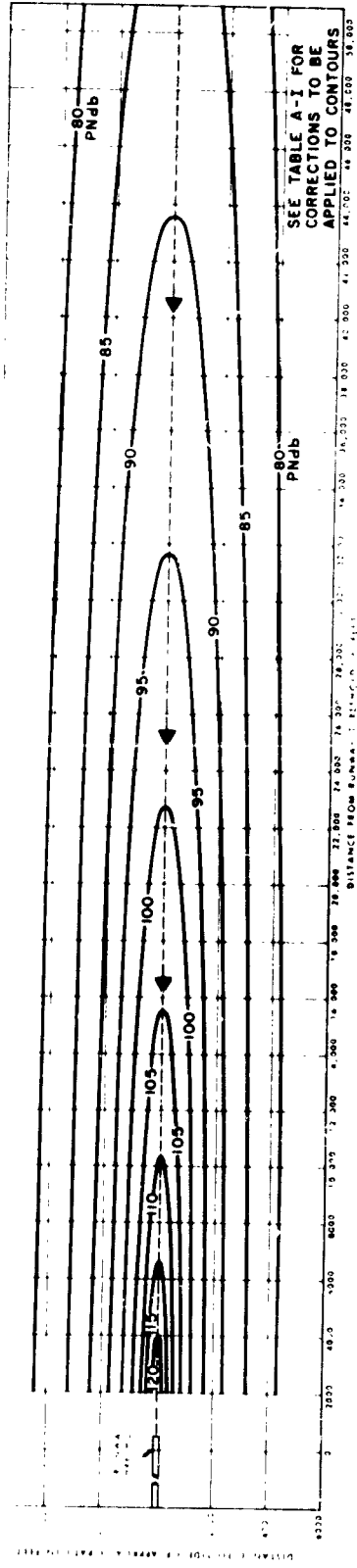
\*\* Two engine piston aircraft from 3,500 to 10,000 lbs gross weight.



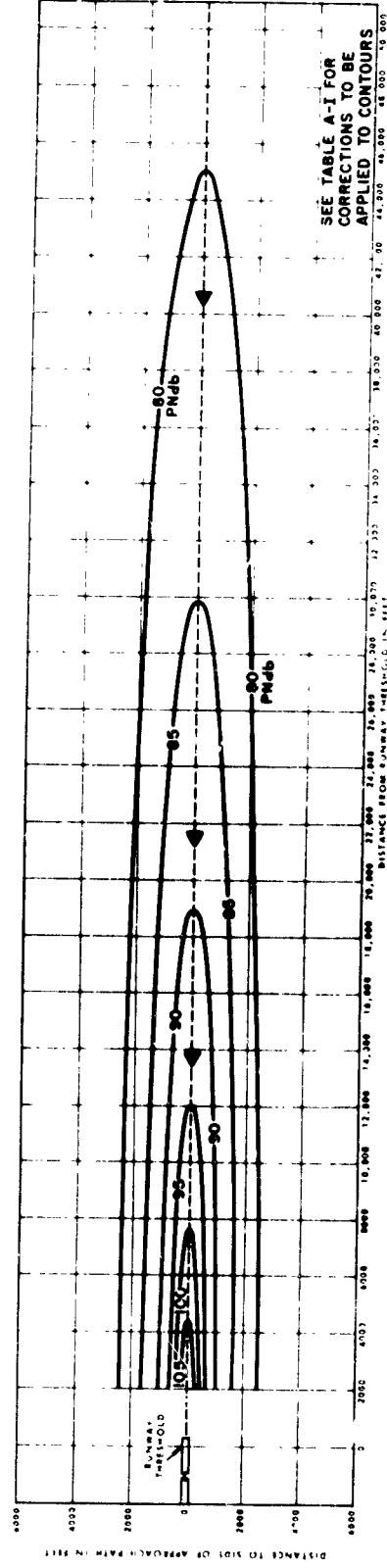
④ MEDIUM AND SHORT RANGE JET TRANSPORT AND BUSINESS JET AIRCRAFT



⑤ TWO ENGINE PROPELLER TRANSPORT AND BUSINESS AIRCRAFT  
PERCEIVED NOISE LEVEL CONTOURS FOR TAKEOFFS  
OF JET AND PROPELLER AIRCRAFT



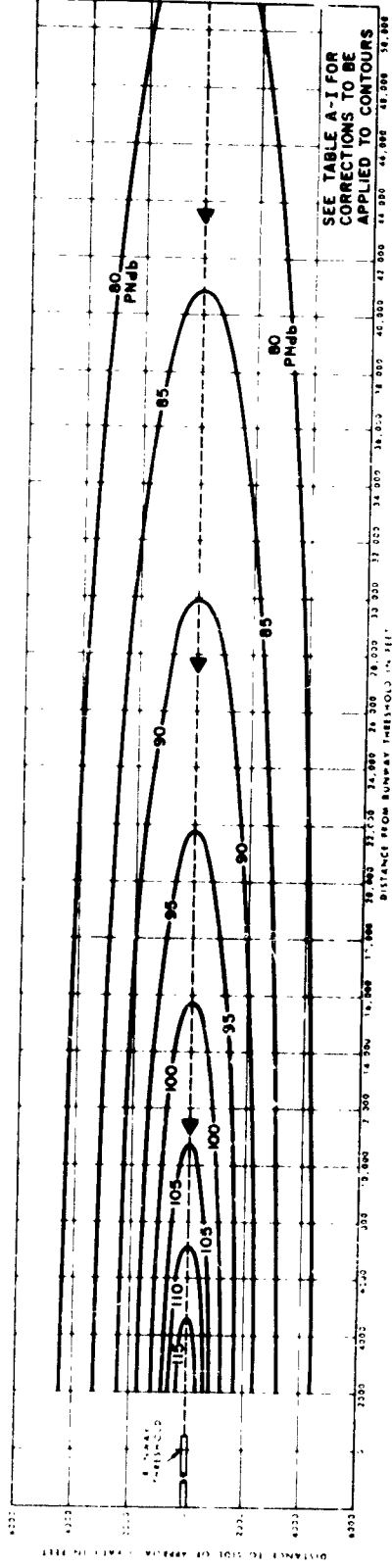
① MEDIUM AND SHORT RANGE JET TRANSPORT AND BUSINESS JET AIRCRAFT



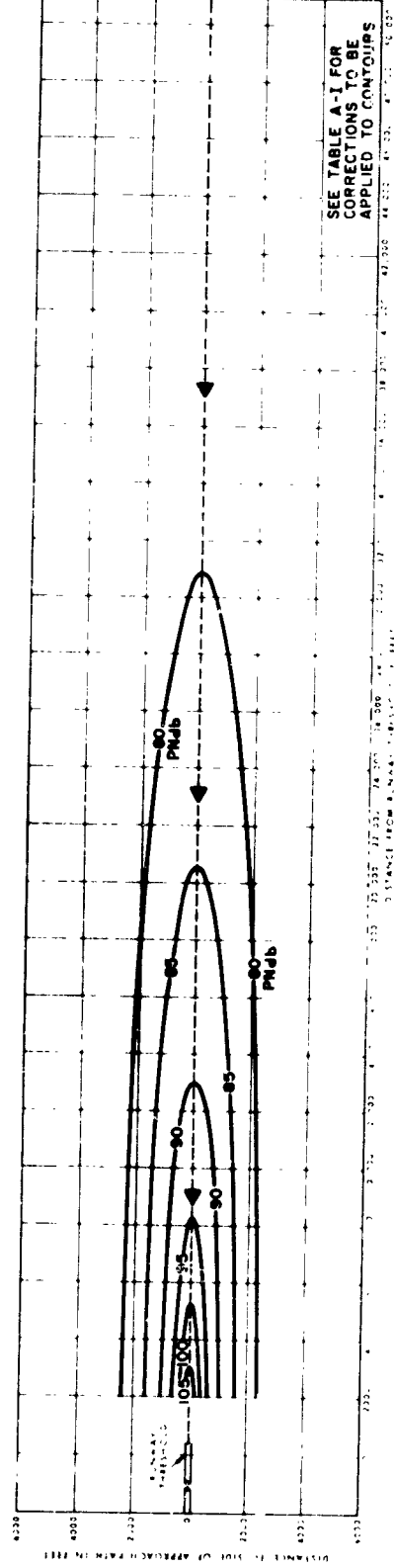
② TWO ENGINE PROPELLER TRANSPORT AND BUSINESS AIRCRAFT  
PERCEIVED NOISE LEVEL CONTOURS FOR INSTRUMENT  
LANDINGS OF JET AND PROPELLER AIRCRAFT

CONTOUR SET 10



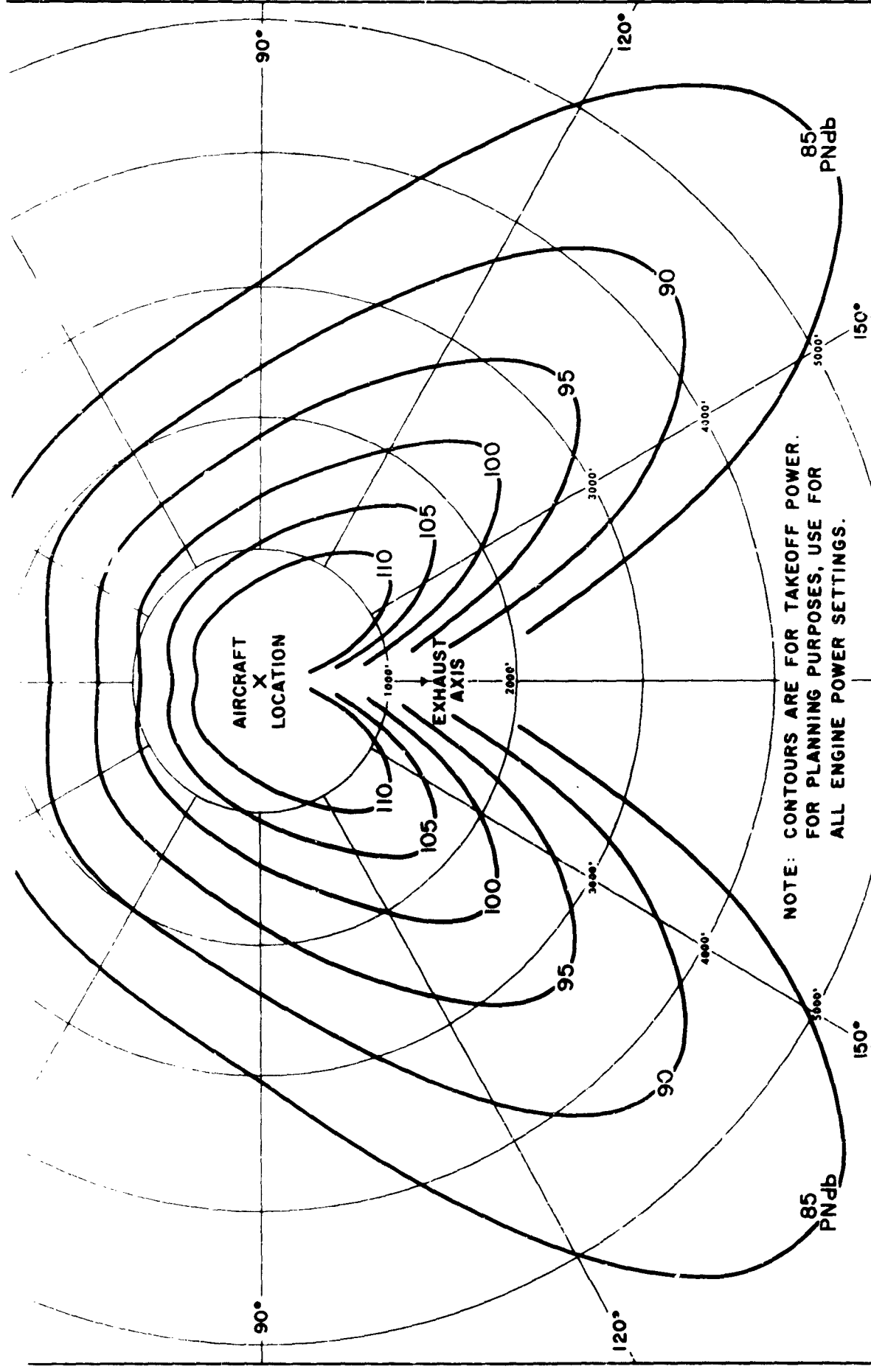


① MEDIUM AND SHORT RANGE JET TRANSPORT AND BUSINESS JET AIRCRAFT



② TWO ENGINE PROPELLER TRANSPORT AND BUSINESS AIRCRAFT  
PERCEIVED NOISE LEVEL CONTOURS FOR VFR AIRCRAFT  
LANDINGS OF JET AND PROPELLER AIRCRAFT

CONTOUR SET II



PERCEIVED NOISE LEVEL CONTOURS - ONE ENGINE RUNUPS  
CIVIL AND MILITARY JET AIRCRAFT WITH TURBOFAN ENGINES

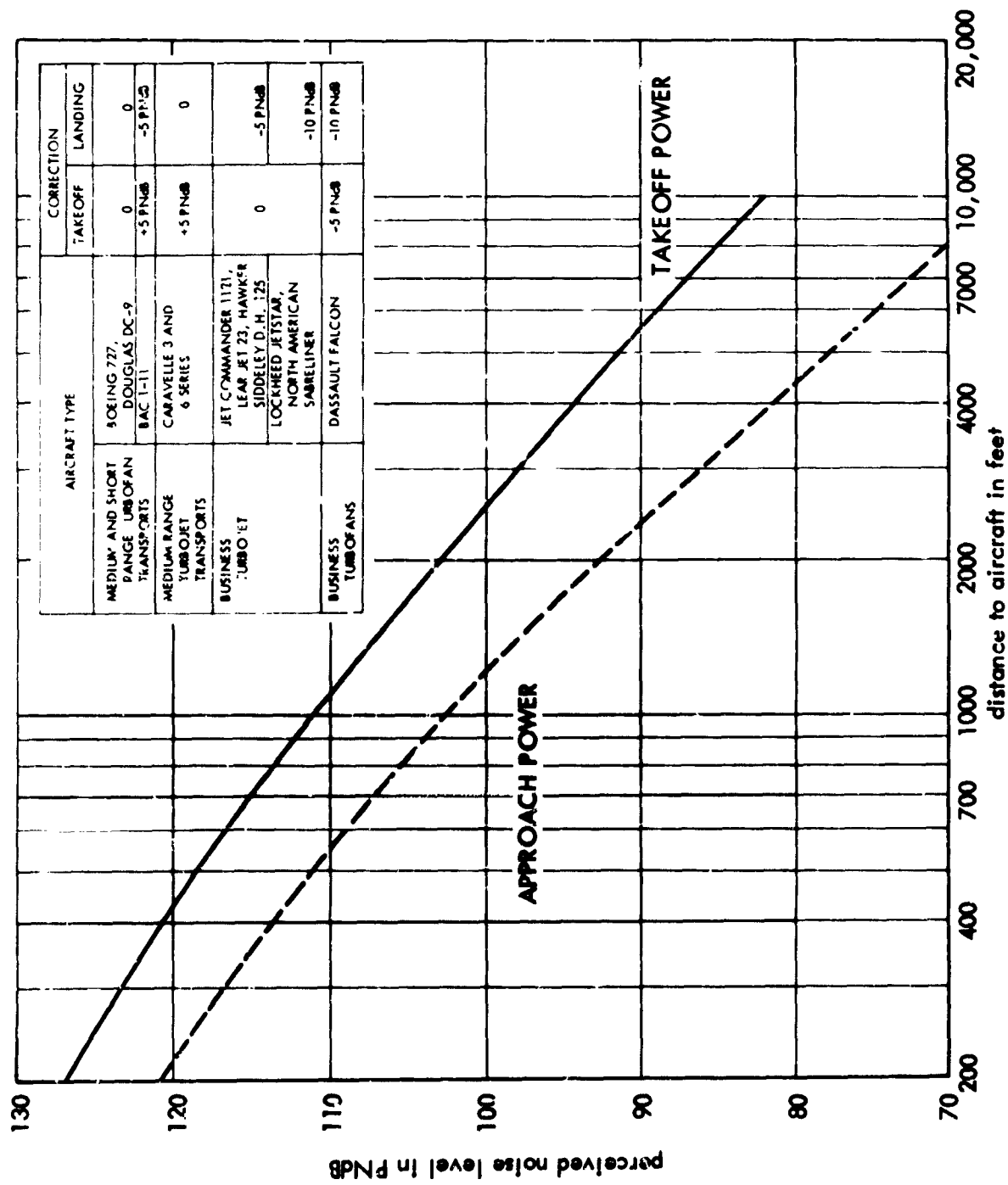


FIGURE A-1. GENERALIZED VARIATION OF PERCEIVED NOISE LEVEL WITH DISTANCE FOR CIVIL MEDIUM AND SHORT RANGE JET TRANSPORT AND BUSINESS JET AIRCRAFT

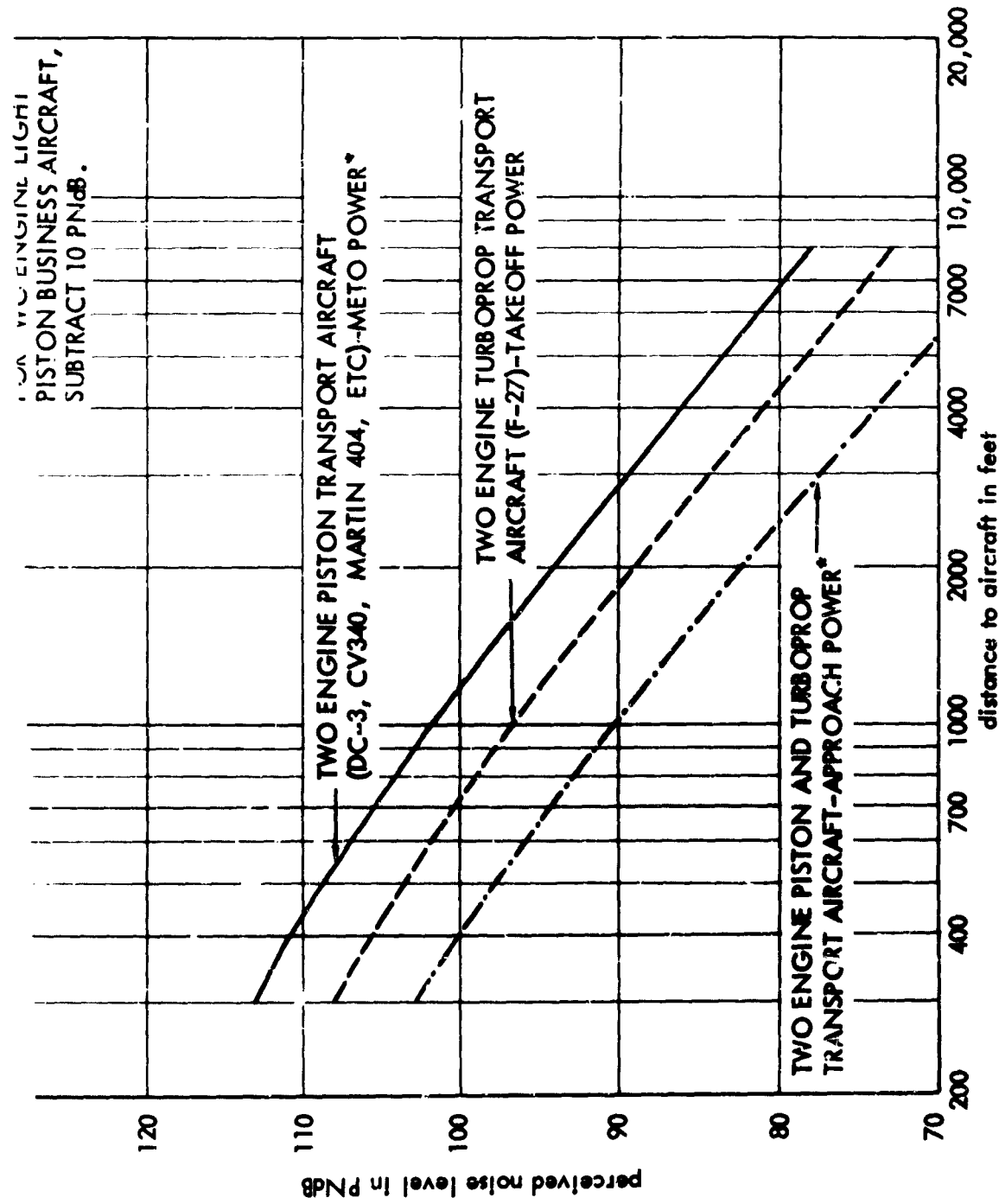


FIGURE A-2. GENERALIZED VARIATION OF PERCEIVED NOISE LEVEL WITH DISTANCE FOR TWO ENGINE PROPELLER TRANSPORT AND BUSINESS AIRCRAFT

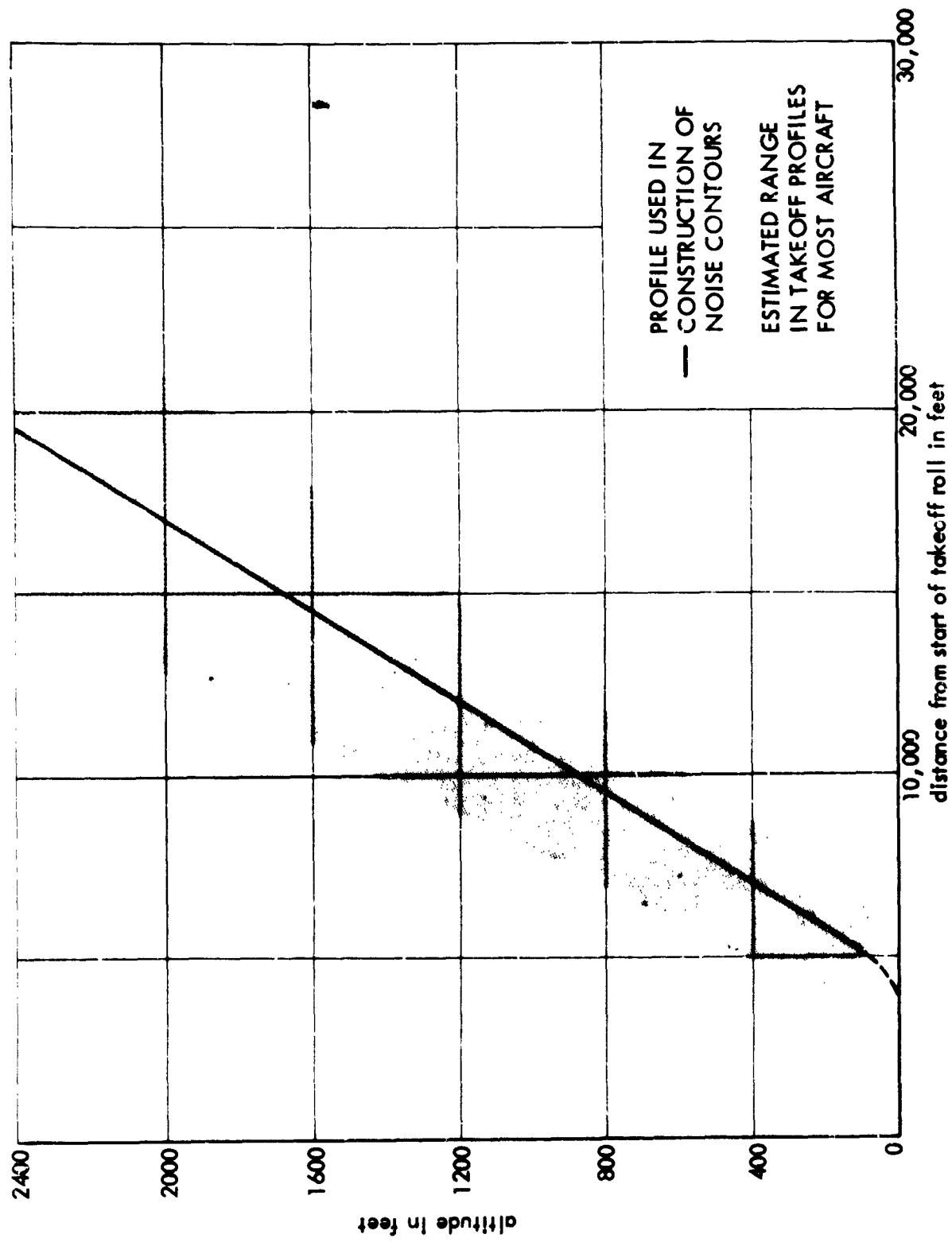


FIGURE A-3. GENERALIZED TAKEOFF PROFILE FOR MEDIUM AND SHORT RANGE JET TRANSPORT AIRCRAFT (BOEING 727, BAC 1-11, DOUGLAS DC-9, AND CARAVELLE SERIES 3 AND 6) AND BUSINESS JET AIRCRAFT

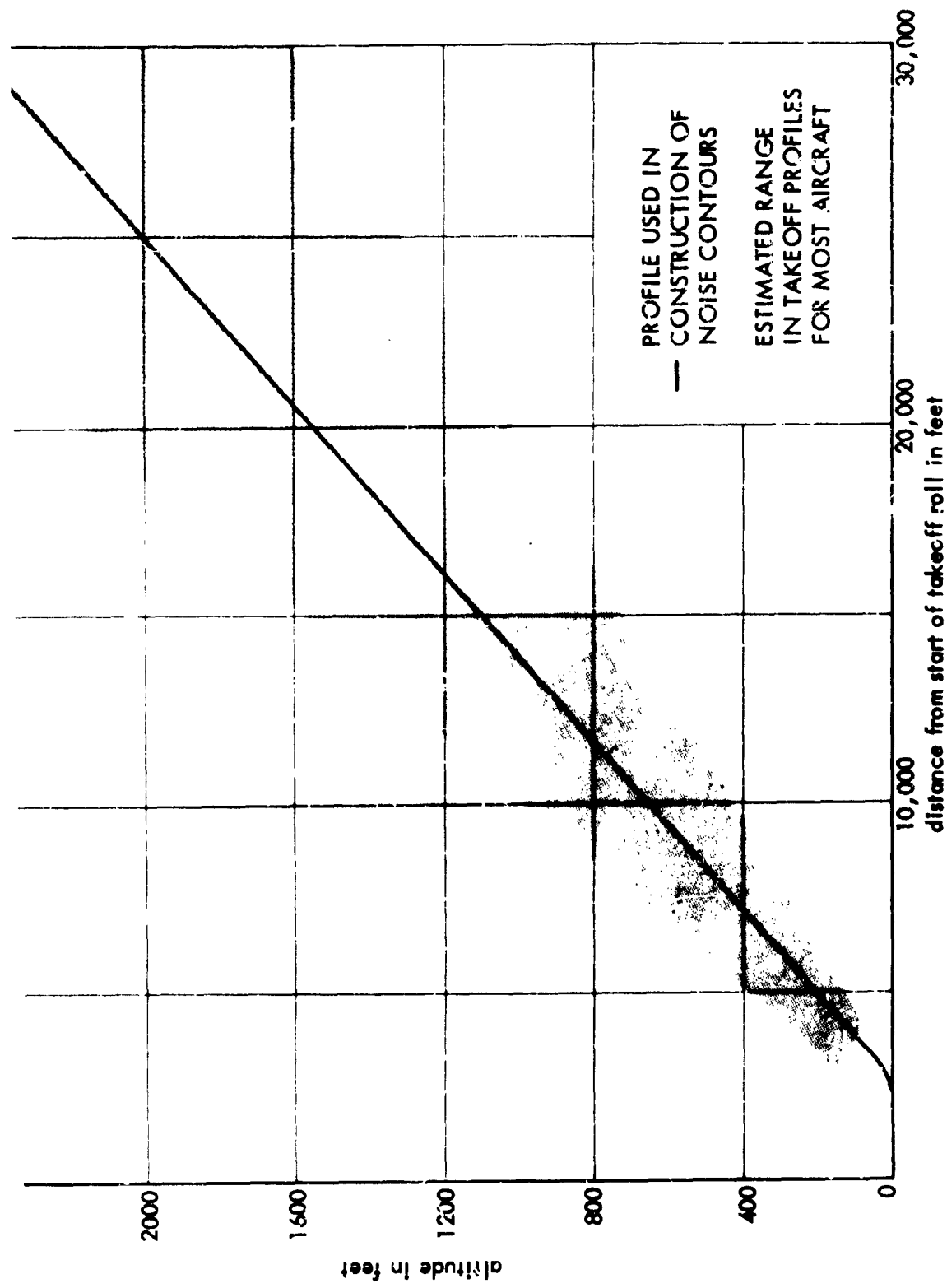


FIGURE A-4. GENERALIZED TAKEOFF PROFILE FOR TWO ENGINE PROPELLER TRANSPORT AND BUSINESS AIRCRAFT